GRAND RIVER BASIN
WATER MANAGEMENT STUDY

Ontario

GRAND RIVER IMPLEMENTATION COMMITTEE

1982

GRAND RIVER BASIN WATER MANAGEMENT STUDY

ERRATA

Please note the following corrections as underlined:

Page (v)

Figure 2.1	Location Map of the Grand River basin
Figure 4.1	Effects of reservoir operation upon 1977 flood at Cambridge (Galt)

Page (vi)

Figure 10.11	Present value of costs and net benefits of main plans versus population projections

Page (viii)

Table 9.3A	Total Costs of Plans A1 and A2
Table 9.4A	Total Costs of Plan A3 - Everton Reservoir
Table 9.4B	Total Costs of Plan A4
Table 9.7A	Total Costs of Plans B1 and B2
Table 9.10A	Total Costs of Plans C1, C2 and C3
Table 9.12A	Total Costs of Plan D
Table 10.3	Summary Table of Costs and Benefits for Main Plans - Medium Population Projection

Page 6.5 - Table 6.3 Summary of Existing Municipal Water Supplies

misplaced line - Arkell Springs should be included as a source of water supply for Guelph.

Page 9.13 - Section: Flood Damage Reduction - 1st Column, 5th line

The difference in cost between the two plans is approximately $23 million ...

Page 9.13 - Table 9.5 Costs for Flood Protection Measures Included in Plan B

Footnote - **Total cost of construction of the Montrose reservoir. Approximately one half of the cost can be allocated towards flood control and one half of the cost can be allocated towards flow augmentation for water quality improvement.

/...2

GRAND RIVER BASIN WATER MANAGEMENT STUDY

ERRATA (Cont'd.)

Page 9.26 - Table 9.13 Reliability of Meeting Minimum Flow Targets at Kitchener (Doon) and Brantford)

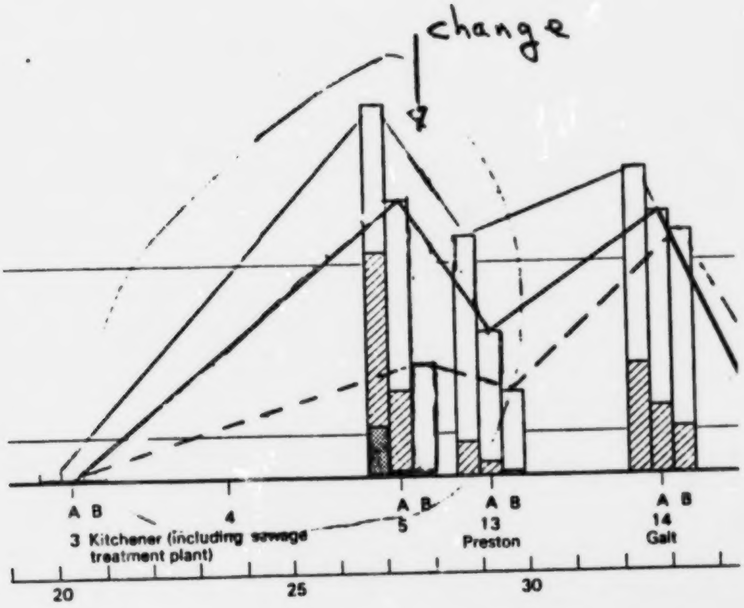
Footnote - 2) Reliability (occurrence) refers to the percentage of years target was met in 17 years of flow record (glossary).

Page 9.27 - Table 9.14 Reliability of Meeting Minimum Flow Targets at Guelph on tne Speed River (at Hanlon above Guelph STP)

Footnote - 1) Reliability (occurrence) refers to the percentage of years target was met in 17 years of flow records (glossary).

Page 10.3 - replace with new page attached to errata. DONE

Page 10.7 - Figure 10.3 (1979 pollutant loadings) At reaçh 5, plan B the graph presently reads 36% of the time below 4 mg/L, 13% of the time below 3 mg/L and 1% of the time below 2 mg/L. The graph should reach 13% of the time below 4 mg/L and 1% of the time below 3 mg/L, as per figure shown below:



of August, average year conditions (Medium population projections).

/...3

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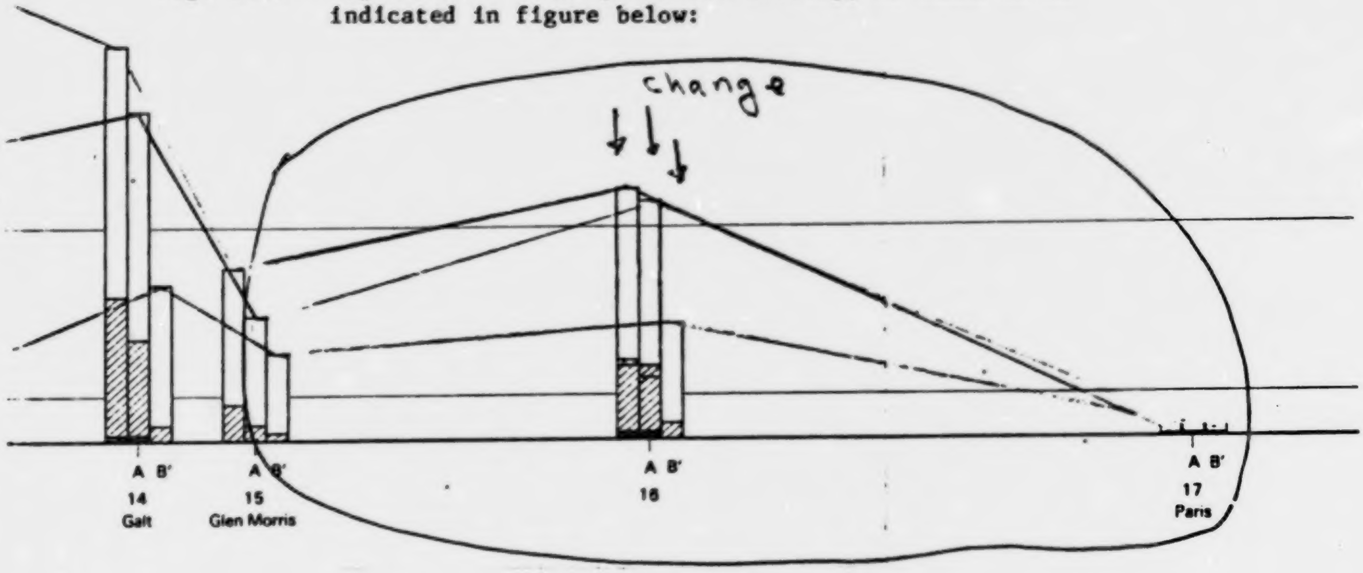
ERRATA (Cont'd.)

Page 10.8 - Figure 10.4 - 2031 pollutant loading, at reach 16 as indicated in figure below:



Page 10.11 - 2nd Column, 1st line

... they would cost more than plan A1 by $6 million and ...

Page 10.14 - 1st Column, 39th line

omit

Page 10.20 - Table 10.3, 1st column entitled plan, 4th row

C
Option 2

Page 11.2 - replace with new page attached to errata. DONE

Page 13.2 - Table 13.1 Principal Agencies Responsible for the Implementation of Water Management Alternatives

under Financial Arrangements for Water Quality - Design, Construction and Maintenance of STPs there should be an asterisk.

under Financial Arrangements for Water Supply - Design, Construction and Maintenance of Water Works there should be an asterisk.

/...4

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Page 14.5 - Public Libraries

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1. SUMMARY AND RECOMMENDATIONS

Summary

The main investigative period of the Grand River Basin Water Management Study extended from 1977 to 1981. Its purpose was to define the water management problems confronting the Grand river basin, and to develop a viable set of alternative water management plans. These plans are designed to meet the following water management objectives:

1) reduce flood damages
2) provide adequate water supply
3) maintain adequate water quality.

This study provides a comprehensive framework to aid elected representatives, officials and citizens in resolving water management problems. The framework is flexible enough to accommodate changing water management priorities and needs. It provides a means by which new projects and other plans can be evaluated.

Large scale water management problems are largely confined to the urban and industrial middle portion of the basin. Here, the Cities of Cambridge and Brantford account for over 85 percent of the $980,000 average annual flood damages experienced within the basin. In the Kitchener-Waterloo-Cambridge area, the existing ground water supply for industrial and domestic consumption will have to be supplemented in the next five years by additional surface and ground water supplies. Low oxygen levels occur during the critical summer period in the central Grand river between Kitchener and Glen Morris and in the Speed river downstream from Guelph. This is caused by organic waste discharges and nutrient inputs from six municipal sewage treatment plants and by upstream rural non-point sources. While water management problems are often the most apparent in the middle portion of the basin, flooding, water shortages and water quality impairment are encountered throughout the basin in rural as well as urban areas. Pollution control measures recommended in this report to maintain or improve the water quality within the river basin will also benefit Lake Erie, particularly measures to reduce the input of nutrients.

The basin study examined twenty-six different water management plans and assessed their relative economic, social and environmental costs and benefits associated with meeting the water management objectives. An evaluation process narrowed these alternatives down to the following main plans (Table 11.1):

1. plan A1 utilizes dyking and channelization to minimize flood damages, advanced sewage treatment to improve water quality, and induced infiltration wells and artificial recharge of aquifers using river water to augment ground water supplies

2. plan A4 is the same as plan A1, but, in addition, preserves the option of using the Montrose reservoir site for possible future water management purposes. Protection of the site can be achieved by acquiring the land as it becomes available and by various planning controls

3. plan B2 proceeds immediately with construction of the Montrose multi-purpose dam and reservoir. Flood damage reduction is provided by the reservoir as well as by dyking and channelization. Water quality is improved by advanced sewage treatment and increased summer flow from the reservoir. Requirements for advanced sewage treatment when compared with plan A are reduced or delayed. Infiltration wells and artificial recharge are used to augment ground water supplies as in plan A1

4. plan C1 is the same as plan A1 with respect to water quality and water supply measures. It provides flood protection through the construction of a single-purpose or dry reservoir on the Conestogo river at St. Jacobs

5. plan D incorporates the flood protection and water quality measures of plan A1 and provides water supply by the construction of a Lake Erie pipeline.

In the initial review of these plans, the basin study assigned lower rankings to plans C1 and D. Plan C1, the St. Jacobs single-purpose reservoir option, will not give adequate flood protection and plan D, the Lake Erie pipeline option, was deemed to be too expensive.

A detailed evaluation of plans A1, A4 and B2 was then carried out. Three of the four public consultation working groups, made up of citizens from different geographical areas of the basin, preferred plan A1 with minimum environmental and social impacts. The fourth group representing the lower portion of the basin, preferred plan B2. The water managers who are charged with the day-to-day responsibility of operating major flood control, water supply and sewage treatment services preferred plan B2 because, in their view, it offered a more reliable and secure water management system.

The overall results of the evaluation incorporating the preferences of all those who participated showed that plans A1, A4 and B2 were ranked very closely.

After a detailed review of the various inputs, the Grand River Implementation Committee, the basin study's co-ordinating committee, identified plan A4 as the preferred plan to meet the water management needs of the basin.

Recommendations

A. The Recommended Plan

1. It is recommended that plan A4 and the measures described in the following recommendations be implemented.

The basin study concluded that plan A4 is cost-effective in meeting the water management objectives. It was preferred over plan B2 (the Montrose dam option) for the following reasons:

a) it is approximately $25 million cheaper than plan B2
b) its environmental and social impacts are moderate. The public participation program indicated that there would be opposition to the selection of plan B2
c) it maintains future flexibility by preserving the option of constructing the Montrose dam if future water quality or water supply problems require it
d) it provides a high degree of flood protection for urban areas
e) it provides for population growth by fully meeting projected municipal water demands and improving water quality in the central Grand river
f) it improves water quality in the central Grand river, although the dissolved oxygen levels will not fully meet the provincial water quality objectives. While plan A4 does not provide as high a water quality as plan B2, it provides a reasonable level of protection for most water uses at a substantially lower cost.

Plan A4 is the same as plan A1 except that land acquisition raises total plan costs by $4 million and increases the social impacts. It was preferred over plan A1 primarily because it maintains future flexibility by preserving the Montrose reservoir lands.

In the opinion of the Grand River Implementation Committee, plan A4 represents the best overall solution to basin water management problems. The recommendation of this plan does not necessarily preclude selection of all or part of another plan. This report defines the water management problems confronting the Grand river basin and establishes a framework within which water management projects and measures can be implemented. The framework is flexible enough to accommodate future water management priorities and needs.

B. Recommendations for Reduction of Flood Damages

The basin study investigated both structural and non-structural methods of reducing flood damages. Structural methods include dyking, channelization, reservoirs and flood proofing. Non-structural methods include regulations, zoning and land use practices.

1. It is recommended that channelization and dyking be constructed to reduce flood damages at the major flood damage centres.

Average annual flood damages at Cambridge, Brantford, Paris, Caledonia, Dunnville and New Hamburg can be reduced 91 percent by channelization and dyking as compared to a 54-56 percent reduction by the Montrose reservoir, the most efficient of the eight reservoirs investigated. Channelization and dyking is the most cost-effective structural method of reducing flood damages. In order to be effective, each dyking and channelization project should be completed as soon as possible.

2. It is recommended that Grand River Conservation Authority policies for regulating floodplain development be continued in accordance with provincial policies and guidelines and that basin municipalities incorporate floodplain restrictions in their official plans and zoning by-laws.

Regulating floodplain development is the best means of reducing or eliminating future flood damages. While structural projects such as dyking and channelization are useful in reducing flood damages, they do not guarantee immunity from floods at all places and at all times.

3. While existing Grand River Conservation Authority policies control the placing and dumping of fill in defined areas, it is recommended that these policies be strengthened by the inclusion of a registered fill line along the river valleys.

Section 28 (f) of the Conservation Authorities Act enables conservation authorities to prohibit or control the placing or dumping of fill in defined areas. In order to enforce this section of the Act, the Authority must designate the area affected by such dumping with fill lines. At present, only specific source areas are protected by fill lines. Designated areas should be expanded to include basin watercourses.

4. It is recommended that the Eramosa valley wetlands be preserved and protected from development by planning controls and by acquisition.

These wetlands adjacent to the river reduce flows by retarding runoff and reducing peak flows. They also maintain a high water quality by acting as buffer strips between the adjoining agricultural lands and the river. A high water quality ensures a low cost supplementary water supply for Guelph and a suitable habitat for a cold-water fishery in the Eramosa river.

5. It is recommended that a study be carried out to determine what land use practices are causing an increase in flood flows and flood volumes on the Grand river and what the effects of future land use practices upon flood flows might be.

At Cambridge (Galt), flood volumes have increased 18 percent and the frequency of flood occurrences has more than doubled in the last forty years, but the study was unable to come to a firm conclusion as to the causes.

C. Recommendations for Providing Adequate Water Supply

The basin study determined that the future water needs of the major urban areas can be obtained by:

a) developing new ground water sources for Cambridge and Guelph
b) developing a new surface water source from the Grand river for Waterloo and Kitchener
c) continued withdrawal from the Grand river for Brantford.

All other basin communities except Elora and Fergus can meet future demands from existing supplies. Elora and Fergus can meet future demands by developing new ground water sources.

1. It is recommended that the municipal ground water supplies for Kitchener-Waterloo be supplemented by further water withdrawals from the Grand river.

These withdrawals can be accomplished by induced infiltration wells near the river and by pumping from the river to recharge ground water at the Mannheim well field. Testing is presently being carried out by the Regional Municipality of Waterloo to determine the feasibility of this scheme.

2. It is recommended that prior to the final development of the above water supply system:

a) industrial organics presently seeping from abandoned industrial waste disposal sites at Breslube Enterprises, near Kitchener, be eliminated or prevented from reaching the adjacent Grand river
b) a water quality surveillance program be established to evaluate risks from possible contamination of the water supply from any sources of synthetic organic compounds.

The most notable potential sources of organic chemicals are the Uniroyal Ltd. plant at Elmira on Canagagigue creek and the Waterloo sewage treatment plant on the Grand river. The recommended surveillance program should be developed to protect existing and future surface water supplies, particularly for the Cities of Kitchener, Waterloo and Brantford.

3. It is recommended that:

a) new ground water supplies be developed near Cambridge to meet future demands
b) the City of Guelph investigate the feasibility of developing new ground water supplies, directing its attention toward the southeast of Guelph in order to meet future demands past the year 2001
c) Elora and Fergus carry out test drilling in a nearby buried bedrock valley to assess its potential for future municipal supplies.

A recent study by the Regional Municipality of Waterloo indicated that there are additional ground water supplies located in the areas east and south of Cambridge.

For Elora, Fergus and Guelph, it is estimated that existing supplies can meet average daily demands for a 2001 medium population projection. The Grand river basin study has identified favourable locations for test drilling in these areas.

4. It is recommended that a ground water quality network be established to monitor the major water supply aquifers within the basin.

A ground water surveillance network should be established in the basin to deal with existing site-specific problems of contamination or possible contamination of usable ground water supplies. In particular, the network should monitor heavy metal, pesticides and other inorganic and organic compounds. This network should be established as soon as possible. This undertaking should be carried out in conjunction with the surface water surveillance program recommended in C.2 (b).

5. It is recommended that the water conservation program be continued in the Regional Municipality of Waterloo, particularly in Waterloo, Kitchener and Cambridge, in order to reduce municipal water demands. For other municipalities, the pursuit of water conservation programs should be evaluated in relation to future needs and supply capabilities.

Water conservation programs embrace a range of actions that aim at reducing average and maximum day municipal water demands. A moderate conservation program could be expected to reduce average day demand in Kitchener-Waterloo by 10 percent, and in Cambridge by 15 percent.

Conservation practices that have been adopted in Guelph are supported and encouraged in light of the potential water supply problem that may occur after the year 2001.

Included in any conservation program should be the consideration of revising the existing rate structure. Where appropriate, municipalities should consider moving from a decreasing rate structure to a rate structure that encourages water conservation.

System losses or unbilled consumption appear to be approximately 9 percent higher than the provincial average for Guelph and Brantford. Existing programs to trace and reduce these losses should be continued.

D. Recommendations to Maintain Adequate Water Quality

The basin study concluded that water quality in the central Grand river can be improved by increased levels of sewage treatment at the Kitchener and Waterloo sewage treatment plants. Some improvement in water quality can also be obtained by reducing upstream rural non-point sources, particularly through the use of erosion control measures.

Water quality in the Speed river will be improved by the recently completed advanced sewage treatment facilities at Guelph. If required, further improvement can be attained by the installation of additional phosphorus removal facilities.

1. In order to increase dissolved oxygen levels and eliminate ammonia toxicity in the central portion of the Grand river, it is recommended that advanced sewage treatment facilities be installed at the Kitchener sewage treatment plant as soon as possible, and at the Waterloo sewage treatment plant at a later date depending on population growth (advanced treatment at the Waterloo plant would be needed by the year 2001 for a medium population projection).

An increased level of sewage treatment at Kitchener and Waterloo will improve the water quality to a reasonable level in the central Grand river, but the provincial water quality objective for dissolved oxygen of 4 mg/L will not always be met in certain sections. Plan B2, through the use of flow augmentation from the Montrose reservoir, comes closest to achieving the objective.

Converting ammonia nitrogen to the nitrate form using rotating biological contactors (RBCs) and accompanying dual-media filters at Kitchener and Waterloo is one method of improving the quality of sewage effluent, thus increasing dissolved oxygen levels and reducing ammonia toxicity in the rivers. The cost of this treatment is included in all plan cost estimates.

Achieving the dissolved oxygen objective continuously in all sections of the central Grand river would require drastic reductions of oxygen-demanding wastes and phosphorus from all point and upstream rural non-point sources. Such large reductions from all point sources would be exceedingly expensive. Large reductions from non-point sources may be difficult to achieve. Reductions will require long-term, continuing improvements in technology and land use practices.

2. It is recommended that the impact of the Guelph advanced sewage treatment facilities on the water quality of the lower Speed river be evaluated throughout the next few years to determine if additional treatment is required.

The total effluent characteristics of the recently completed sewage treatment addition (rotating biological contactors and dual-media filtration) are not yet known. Assumed effluent characteristics were used for analyzing the basin study water management alternatives. If after a 2-3 year evaluation period, the Speed river between Guelph and Cambridge (Hespeler) is still experiencing very low oxygen levels, consideration must be given to reducing further the levels of phosphorus in the sewage effluent. One method of reducing phosphorus considered by the basin study is the addition of chemical treatment and multi-media filtration at the Guelph sewage treatment plant. The cost of this treatment is included in all the plan cost estimates.

3. In order to evaluate the effects of existing and proposed water quality improvements, it is recommended that the Ministry of the Environment and the Grand River Conservation Authority jointly maintain the existing six continuous water quality monitoring stations in the central Grand river and the lower Speed river.

With the addition of remote sensing, these gauges would also aid in the real-time operation of existing reservoirs and sewage treatment plants.

4. It is recommended that the Ministry of Agriculture and Food, as the lead agency, carry out studies to determine the effectiveness, type and site specific locations of rural non-point source controls. Initially, efforts should be concentrated in the Canagagigue creek, middle Grand river, Irvine creek, Cox creek, Conestogo and Nith river sub-basins.

Studies should be carried out to determine:

a) those critical areas contributing the greatest loadings of sediments and nutrients to the streams. Improved management practices should be concentrated in these areas
b) the applicability and effectiveness of various rural non-point source management practices
c) the relation between the costs of these measures and the agricultural and water quality benefits obtained
d) priority of the areas to be treated.

5. It is recommended that urban areas adopt storm water management practices to reduce local flooding and improve stream water quality.

This study has shown that urban runoff does not affect the flood peak flows of the major rivers nor does it materially affect the dissolved oxygen regime in the Grand or Speed rivers. However, urban runoff increases bacteria levels immediately downstream of the major urban centres on these rivers. Increased levels of bacteria pose potential health hazards for incidental contact such as children playing at the river's edge. Urban runoff causes more serious flooding and water quality problems in small tributaries by raising stream levels rapidly and increasing concentrations of metals, bacteria and nutrients.

6. In order to achieve the flow requirements of plan A4 for both water supply and water quality, it is recommended that the Grand River Conservation Authority operating policy for the existing reservoirs be modified to achieve the following target flows:

Location	Period	Minimum Flow Targets		Operating Range*	
		Present	Recommended	Present	Recommended
Grand R. at Shand Dam	June-Sept.	2.8 m^3/s	2.8 m^3/s	N/A	N/A
	May-Oct.	2.8 m^3/s	2.8 m^3/s	N/A	N/A
	Nov.-Apr.	None	2.8 m^3/s	N/A	N/A
Grand R. at Doon	May-Oct.	11.3 m^3/s	9.9 m^3/s	11.3 - 12.7 m^3/s	9.1 - 10.8 m^3/s
	Nov.-Dec.	No Target	7.1 m^3/s	N/A	6.2 - 7.9 m^3/s
	Jan.-Apr.	Ice ** Conditions			
Grand R. at Brantford	May-Oct.	17.0 m^3/s	17.0 m^3/s	17.0 - 18.4 m^3/s	15.6 - 18.4 m^3/s
	Nov.-Dec.	No Target	No Target	N/A	N/A
	Jan.-Apr.	Ice ** Conditions			
Conestogo R. at Conestogo Dam	May-Oct.	2.1 m^3/s	2.1 m^3/s	N/A	N/A
	Jan.-Apr.	No Target	No Target	N/A	N/A
Speed R. at Guelph Dam	May-Oct.	0.6 m^3/s	0.6 m^3/s	N/A	N/A
	Jan.-Apr.	No Target	No Target	N/A	N/A
Speed R. at City of Guelph (Hanlon Expressway)	June-Sept.	1.1 m^3/s	1.7 m^3/s	N/A	N/A
	May-Oct.	1.1 m^3/s	1.1 m^3/s	N/A	N/A
	Jan.-Apr.	Ice ** Conditions			

* Because of the travel time from the reservoirs to the point of interest, the daily flows can vary from the target flow. The travel times from the reservoirs to Doon and Brantford are 30 and 48 hours respectively.

** When the river is ice covered, flows cannot be continuously measured.

N/A Not Applicable

E. Recommendation to Protect the Montrose Reservoir Site

1. It is recommended that the Montrose reservoir site be protected for possible future water management purposes.

Protection of the Montrose reservoir site can be achieved by land acquisition and planning controls. Acquisition can be carried out over time by purchasing the land at the prevailing market price. Planning controls can be utilized in the form of land use regulations and zoning.

At some time in the future the land can either be sold, used for construction of a dam and reservoir, or preserved for other uses. In the meantime, the existing agricultural land use can be maintained and the site protected from development.

F. Recommendations to Implement the Plan and Co-ordinate Government Activities

1. It is recommended that the water management plan be implemented by existing government agencies.

Traditionally, the components of plan A4 have been implemented by the following agencies:

Flood control, flood warning, dyking and channelization	— Grand River Conservation Authority Municipalities Ministry of Natural Resources
Flood proofing	— Individual landowners
Water supply projects and sewage treatment plants	— Municipalities Ministry of the Environment
Acquisition of Montrose reservoir land	— Grand River Conservation Authority
Non-point source pollution control	— Individual landowners Municipalities Grand River Conservation Authority Ontario Ministry of Agriculture and Food Ministry of the Environment Ministry of Natural Resources
Planning controls	— Municipalities Grand River Conservation Authority Ministry of Municipal Affairs and Housing Ministry of Natural Resources

2. It is recommended that a committee be established to co-ordinate the activities of the existing agencies in implementing the water management plan preferred by governments.

The committee would consist of members from implementing ministries and agencies and basin municipalities. The committee would deal with the scheduling and implementation of measures selected to meet the water management needs of the basin.

3. It is recommended that such a co-ordinating committee play a lead role in carrying out a periodic re-evaluation of the plan, co-ordinating investigations and recommending new or modified alternatives to achieve the water management objectives of the Grand river basin.

The selected basin plan should be reviewed on an on-going basis and re-evaluated every five years. This will ensure that the plan is kept abreast of the latest developments in water resources management and that the assumptions made in deriving the original plan are still valid.

4. It is recommended that the co-ordinating committee be assisted in its on-going review by a small technical staff responsible to the co-ordinating committee.

The technical staff would aid the co-ordinating committee in reviewing the management plans and undertaking specific water management studies. The capability of this staff can be expanded as the need requires by drawing upon the expertise of the basin universities and other agencies.

2. INTRODUCTION

2.1 Background

The Grand river, located in southwestern Ontario, originates near the Village of Dundalk and picks up its major tributaries, the Conestogo, Nith and Speed rivers as it winds its way over 300 kilometres (km) (186 miles) southeast to Lake Erie collecting water from a drainage area of 6,965 square kilometres (km^2) (2,689 square miles). The average annual flow of the Grand river is 55 cubic metres per second [(m^3/s) (1,942 cubic feet per second (cfs)] at the mouth. The flow can range from a maximum of 1,800 m^3/s in the spring to a minimum of 6 m^3/s in the winter.

Land use within the basin is varied, with agricultural and rural land uses dominant in the northern and southern portions and urban land uses concentrated in the central portion. Agricultural and urban land uses respectively comprise 78 percent and 3 percent of the basin area. Wooded and/or idle areas account for approximately 19 percent of the basin area, while less than 1 percent lies in other uses. The bulk of the basin's population resides in the Cities of Kitchener, Waterloo, Cambridge, Guelph and Brantford and places high demands and stresses on the surface and ground water resources of the central basin (Fig. 2.1).

2.2 The Problems

Three main water management problems have been identified: flood damage, degraded water quality and water supply shortages. These problems are historic in nature and occur mainly in the middle part of the basin. However, similar problems occur locally throughout the basin.

Early settlement of the basin during the 1800s by Europeans focused on the Grand river and its tributaries as the nucleus for both urban and rural development. Mill dams were built to provide water power and the rivers were used to supply water and provide convenient disposal for domestic and industrial wastes. Because the floodplain serves a natural function in conveying and storing water during periods of high flow, urban development on floodplains gradually created conflicts between land use and flood hazards. Moreover, the probability of flooding in certain communities such as Cambridge (Galt), has increased since the early 1900s (Ref. 1). Despite an active program of restricting floodplain development and constructing dams and dykes to reduce flooding problems, average annual flood damages in the basin exceed $980,000.

The most serious water quality impairment problems are found in the central basin. Oxygen-demanding organic wastes discharged from municipal sewage treatment plants deplete the river's oxygen supply. Concurrently, nutrient inputs from sewage treatment plants and non-point sources stimulate the growth of aquatic plants and algae which add oxygen during the day but consume large amounts of oxygen during the night. During the summer months, the combined effect of these two processes creates severe oxygen depletions and excessive plant growth, particularly in the Speed river for a distance of 20 km (12 miles) below Guelph and in the Grand river over a 40 km (25 mile) distance between Kitchener and a point north of Paris. Toxic substances, suspended solids, trace contaminants and bacteria also pose water quality problems in some river reaches.

Water shortage problems in the basin relate principally to urban growth in the Kitchener-Waterloo-Cambridge area. Past water shortages, particularly during the summer months, have led to the imposition of water use restrictions. To accommodate future urban growth, the existing ground water supplies must be supplemented by additional surface and ground water within the next five years. With continued use of river water by the communities of Brantford and Cayuga and probable future extraction of river water to supplement water supplies by the Cities of Kitchener, Waterloo and Cambridge, careful water quality and quantity control will be required.

2.3 The Issues

Several issues allied with the problems discussed previously stimulate controversy in dealing with some past or proposed water management solutions.

One issue is the perceived inequity of constructing an additional multi-purpose dam and reservoir, the Montrose, in a rural area to solve urban problems of flooding and water quality (Fig. 9.2).

A second issue focuses on the propriety of urban municipalities abstracting increasing amounts of ground water from rural areas. Although past ground water interference problems in areas of high abstraction near Kitchener and Waterloo have been corrected to a high degree by the Regional Municipality of Waterloo under the provisions of the Ontario Water Resources Act, future conflicts may arise as a result of increases in water demand.

An issue associated with the flood damage problem is the question of governments restricting rural and urban development in the floodplain.

Another issue involves the question of the effect of agricultural runoff on flow and water quality problems in the river.

An ever-recurring issue is the preference of some urban and rural citizens for a Great Lakes pipeline to supply the needs of Kitchener, Waterloo and Cambridge over alternative ground water or river sources of supply.

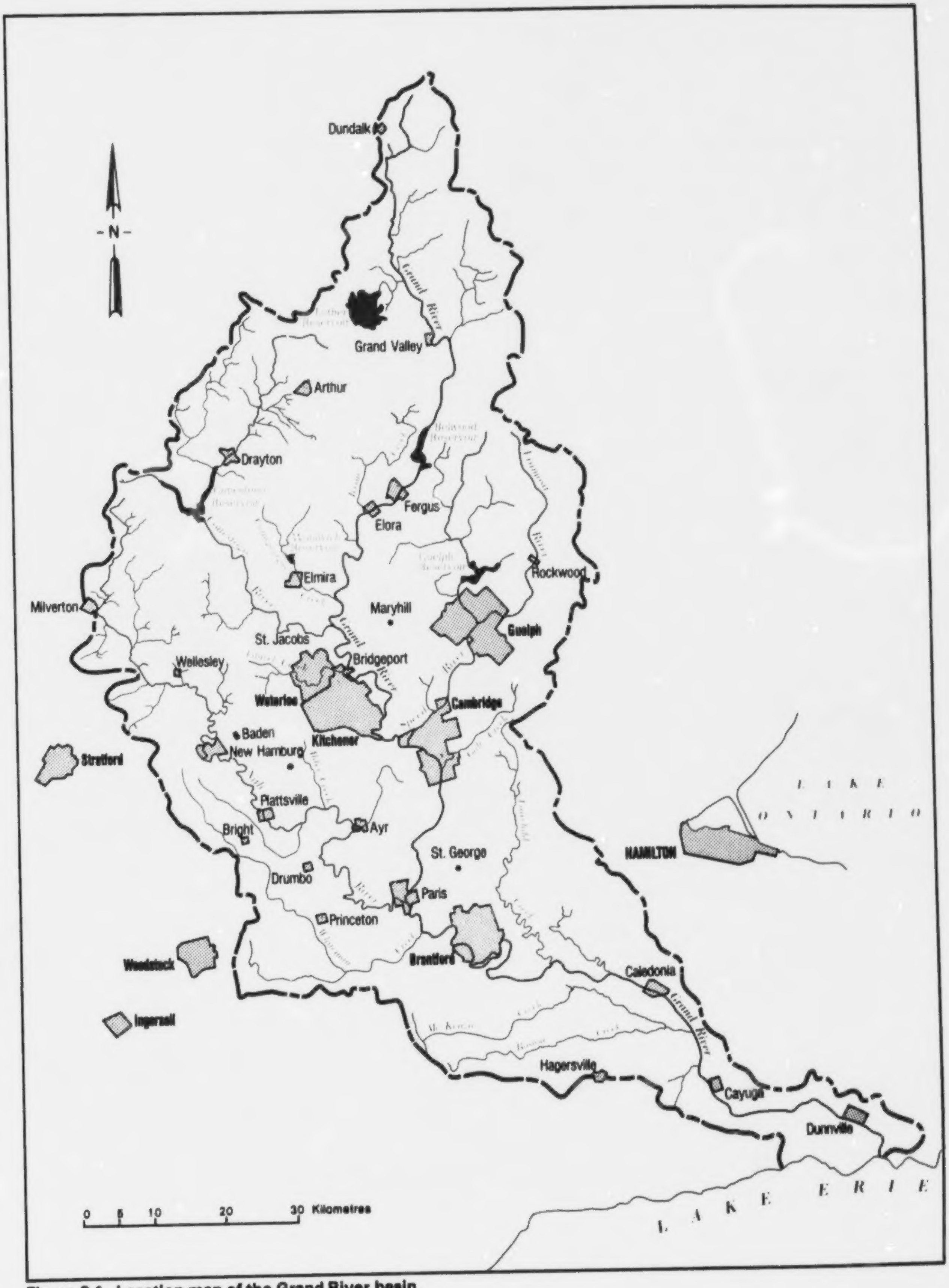

N
Dundalk
Grand River
Luther Reservoir
Grand Valley
Arthur
Belwood Reservoir
Drayton
Conestogo Reservoir
Fergus
Elora
Woolwich Reservoir
Guelph Reservoir
Rockwood
Elmira
Milverton
Maryhill
Guelph
St. Jacobs
Bridgeport
Wellesley
Waterloo
Cambridge
Speed River
Baden
Kitchener
New Hamburg
Stratford
Nith River
Plattsville
Ayr
Bright
St. George
Drumbo
Paris
Princeton
Woodstock
Brantford
Caledonia
Ingersoll
Hagersville
Cayuga
Dunnville
HAMILTON
LAKE ONTARIO
LAKE ERIE
0 5 10 20 30 Kilometres

Figure 2.1. Location map of the Grand River basin.

2.4 The Basin Study

With the responsibility for solving flood damage, water quality and water shortage problems divided among several government bodies, it was felt that an inter-agency, basin-wide study was required to provide a comprehensive water management plan. The necessity for developing a comprehensive plan was acknowledged in two provincial reports entitled "Review of Planning for the Grand River Watershed", 1971 (Ref. 2) and "Royal Commission Inquiry into the Grand River Flood", 1974 (Ref. 3).

Between the years 1972 and 1977, many water management problems were investigated on an individual basis co-operatively by the Province, basin municipalities and the Grand River Conservation Authority, the results of which provided base data for a more comprehensive water management study. In 1977, the Grand River Basin Water Management Study was approved. The study was directed by the Grand River Implementation Committee, with members representing the provincial Ministries of Agriculture and Food, Environment, Municipal Affairs and Housing, Natural Resources, Treasury and Economics and the Grand River Conservation Authority (Appendix A). Field investigations and analysis of information on water quality, streamflow, ground water resources and land use practices were completed during the period from 1977 to 1981.

Opinions regarding water management problems and proposed solutions were solicited through a series of public meetings and four public consultation working groups representing the upper, mid-upper, mid-lower and lower regions of the basin (Ref. Tech. Report Nos. 21 and 43).

2.5 Acknowledgements

This report is the product of the constructive efforts of many individuals and agencies whose active co-operation resulted in a comprehensive study. The co-operation was much appreciated and many thanks are extended to all who participated.

In particular, thanks are extended to the Ministries of the Environment and Natural Resources, the Grand River Conservation Authority, and basin municipalities for furnishing staff and facilities. The Province of Ontario provided funding to carry out the study.

UPPER BASIN: Grand river at Elora

3. THE GRAND RIVER BASIN

3.1 Past and Present

Based on physical characteristics, the basin can be divided into three distinct units: upper, middle and lower.

The upper basin is dominated by a gently rolling landscape. Surface materials are composed primarily of silt and clay tills which promote large volumes of runoff. Where the terrain is relatively flat, the runoff process is impeded and swamps such as the Luther marsh result. A combination of steep river grades, 1.6 metres per kilometre (m/km) (8.4 ft/mi), and channels less than 1 metre (3.3 feet) in depth encourage average river velocities of 1.8 metres per second (m/s) (5.9 ft/sec) and contribute to high river discharges. Underlying the upper basin are permeable limestone and bedrock formations which provide high quality ground water sources.

Settlers were attracted to the area, in part because of the availability of water and the potential the river afforded to provide power to operate mills. Although scattered small communities were established, several factors contributed to impede development. Agricultural development in some areas was hampered since a system of artificial drains was required in order to cultivate land or increase its agricultural productivity. Agriculture was also limited by a relatively short growing season. Small grains, hays and improved pasture became predominant agricultural land uses. Furthermore, development was restrained because transportation and communication links were established more intensively in other areas of the basin. In 1980, the population in the upper part of the basin represented less than 5 percent of the total basin population with the majority of people residing in the communities of Dundalk, Grand Valley, Arthur, Drayton, Fergus and Elora.

The middle basin is rugged and hilly, dissected by the broad valleys of the Conestogo and Nith rivers and by extensive areas of alluvial terraces adjacent to the Grand river. Although till deposits are abundant throughout, kame and outwash sands and gravels with some shallow water deltaic and beach deposits predominate. These deposits are generally well drained, and are extensive in the Kitchener-Waterloo area where they form excellent ground water aquifers. The hydrologic characteristics of the river are generally similar to the upper reaches since river channels are shallow and river grades steep. The middle basin is underlain by limestone and bedrock formations which in the east give rise to one of the most productive aquifer complexes in Ontario. To the west, ground water quality in the bedrock decreases as a result of the presence of sulphates and iron in the bedrock. Fortunately, sands and gravels in the western overburden aquifer furnish good quality water.

MIDDLE BASIN: Grand river at West Montrose

MIDDLE BASIN: Grand river at Cambridge (Galt). Note recently constructed dykes in foreground

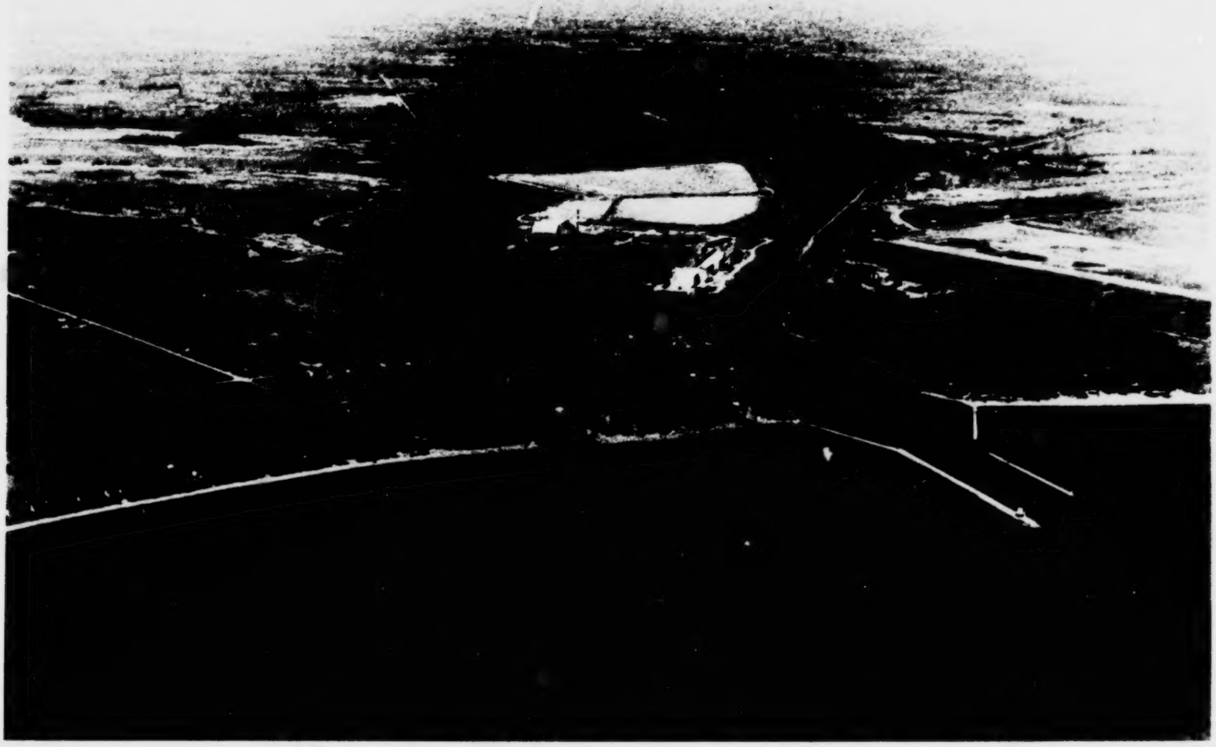
Because of the advantages in terms of abundant, high-quality water supply; potential power for mill operation and electricity; and easily cultivated flats, plus the area's proximity and accessibility to major Ontario centres, the middle basin became the focus for development. Communities which grew around mills and developed on valley flats include Guelph, Galt*, Hespeler*, Preston*, Paris, New Hamburg and Brantford. Major industries established during the formative years focused on the production of food and beverages, clothing, and textiles. Later, additional light and heavy manufacturing industries were established. Favourable climate combined with the well drained and fertile soils of the middle basin promoted cultivation of grains, hay and row crops, particularly in the basins of the lower Conestogo river, Canagagigue creek and Nith river. In 1980, close to 90 percent of the basin residents lived in the middle basin, the majority residing in the Cities of Kitchener, Waterloo, Cambridge, Guelph and Brantford.

A relatively flat terrain is characteristic of the lower basin. Surface materials are composed of sands and silts in the Whiteman creek watershed and a mixture of heavily textured stratified clay and till in the remainder of the basin. Because low infiltration rates and flat terrain promote large volumes of surface runoff and poor outlet conditions, local flooding results. The lower reaches of the river flow through broad river valleys at an average grade of 0.23 m/km (1.2 ft/mi) and an average velocity of 1.2 m/s (4 ft/sec). Low river grades and broad river valleys also contribute to local flooding. Bedrock formations underlying the lower basin provide poor quality ground water with high levels of sulphate.

Early development was hampered by marshy river banks and unproductive agricultural land in the extreme south. However, the production of tobacco and other row crops flourished in the sandy soils of the Whiteman and McKenzie creek basins. With development opportunities focused in the middle basin, settlement in the lower basin occurred in small communities scattered along the river banks. In 1976, less than 7 percent of the basin population inhabited the lower basin, with many of the residents living in the communities of Cayuga, Caledonia and Dunnville.

*These communities were amalgamated in 1973 to form the City of Cambridge.

LOWER BASIN: Grand river



MOUTH OF THE GRAND RIVER: Grand river as it enters Lake Erie

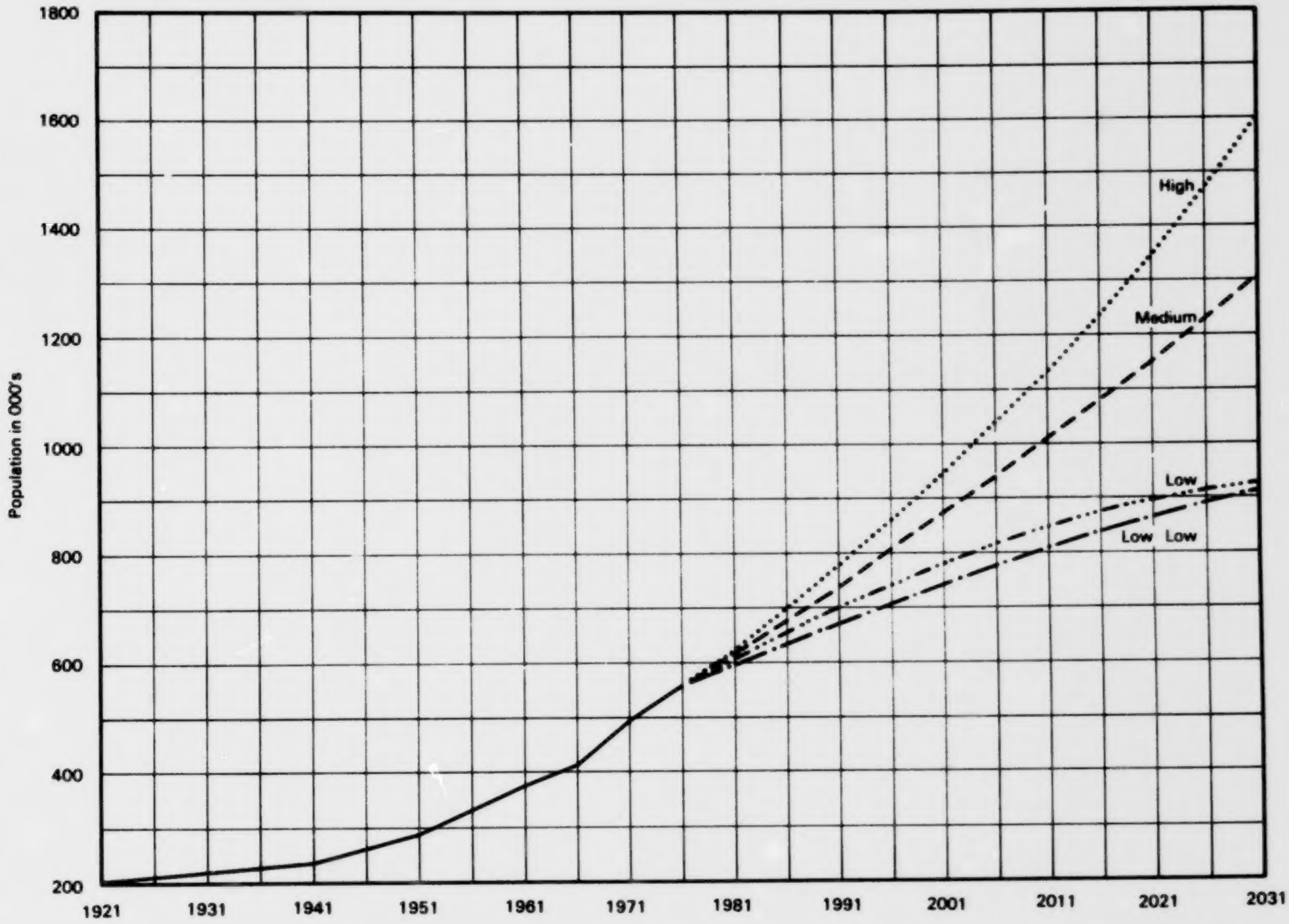


Figure 3.1. Population projections for the Grand River basin.

Table 3.1 Past and Projected Urban and Rural Population Growth Within the Grand River Basin

					2001*				2031**			
CITIES	**1921**	**1941**	**1966**	**1976**	**Low Low*** **	**Low**	**Medium**	**High**	**Low Low*** **	**Low**	**Medium**	**High**
Kitchener	21,763	35,657	91,376	131,801	186,369	208,795	222,486	231,514	221,657	229,724	319,340	367,301
Waterloo	5,883	9,025	29,770	49,972	69,838	86,461	92,131	95,869	83,060	95,128	132,237	152,098
Cambridge	21,416	25,108	51,482	71,482	111,533	116,815	124,474	129,525	132,699	128,524	178,662	205,495
Guelph	18,128	23,273	49,497	70,374	90,250	90,250	115,456	130,469	121,643	121,643	209,133	273,669
Brantford	29,440	31,948	58,395	69,930	89,680	89,680	99,239	109,772	120,875	120,875	151,045	188,575
Total	96,630	125,011	280,520	393,559	547,670	592,001	653,786	697,149	679,934	695,894	990,417	1,187,138
% of watershed population	47.5	53.0	68.2	71.8	74.8	76.0	75.4	74.2	75.2	75.7	76.0	74.2
Average Annual Growth Rate (%)		1.3	3.3	3.4	1.3	1.6	2.1	2.3	1.0	1.0	1.7	2.0
Incorporated Towns and Villages												
Total Population	18,589	20,818	35,961	44,041	59,667	59,667	70,020	80,272	80,869	80,869	112,758	143,974
% of watershed population	9.1	8.8	8.7	8.0	8.1	7.7	8.1	8.5	8.9	8.8	8.7	9.0
Average Annual Growth Rate (%)		0.6	2.2	2.1	1.2	1.2	1.9	2.4	1.1	1.1	1.7	2.2
Rural Areas (including unincorporated rural hamlets)												
Total Population	88,204	89,795	95,118	110,186	127,189	127,189	143,074	161,622	142,146	142,146	199,434	269,332
% of watershed population	43.4	38.0	23.1	20.1	17.4	16.3	16.5	17.2	15.7	15.5	15.3	16.8
Average Annual Growth Rate (%)		0.1	0.2	1.5	0.6	0.6	1.1	1.5	0.5	0.5	1.1	1.6
Total Watershed Population	203,423	235,624	411,599	547,786	734,526	778,857	866,880	939,043	902,949	918,909	1,302,609	1,600,444
Average Annual Growth Rate (%)		0.7	2.3	2.8	1.2	1.4	1.9	2.2	0.9	0.9	1.6	2.0

* Growth rates apply for the years between 1976 and 2001.

** Growth rates apply for the years between 1976 and 2031.

*** Growth rates were estimated only for the Cities of Kitchener, Waterloo and Cambridge.

3.2 Future Trends

3.2.1 Urban

About 80 percent of the basin population resided in urban centres in 1980, with the Cities of Brantford, Cambridge, Guelph, Kitchener and Waterloo having almost 90 percent of the urban population.

In 1980, the basin population was 573,000. Projections indicate that the basin population could range between 735,000 and 939,000 by the year 2001, and between 903,000 and 1,600,000 by the year 2031 (Fig. 3.1). Since most of the population growth is forecast for existing urban centres, the percentage of basin population residing in urban areas is expected to increase to 85 percent. In rural areas, population growth is predicted for unincorporated communities. If these communities were considered urban, the percentage of basin population residing in urban areas would exceed 90 percent after the year 2001 (Table 3.1; and Ref. Tech. Report No. 12).

Expansion of the diverse industrial, commercial and service base within the basin is expected to provide employment opportunities to support additional population growth. In 1980, over 30 percent of the basin residents employed by industry were involved in the production of machinery, metal fabricating and electrical products. The employment opportunities for these activities are anticipated to remain high in the future, while the percentage of people employed by industry as a whole is expected to remain steady. Employment opportunities in wholesale and retail trade; finance, insurance and real estate; and community, business and personal services are predicted to increase significantly, particularly in the major urban centres.

HARVESTING CORN: The primary row crop of the Grand river basin

3.2.2 Rural

Rural land use is not expected to alter dramatically in the future. However, several general trends have been discerned which may change the pattern of agricultural land use. Throughout the basin, an increase in row crop production, with crop rotation being practised to maintain soil nutrients, is forecast, replacing some small grains, hay and improved pasture. A trend towards larger farming units, fewer farmers and specialization of activities is also expected. With the cost of chemical fertilizers increasing rapidly, the use of manure as a nutrient supplement will expand (Ref. Tech. Report No. 8).

In the upper basin, the amount of land cultivated in row crops, mainly corn, may increase significantly, particularly south of the Luther marsh. In poorly drained areas, an increase in land under drainage is expected to increase agricultural productivity.

FEEDLOT OPERATION: Livestock represents an important farm industry in the middle Grand river basin

The most drastic changes in rural land uses are forecast for the middle basin where land is intensively cropped. An increase in row crops, particularly corn, is expected. The production of fresh vegetables in areas adjacent to the major urban centres may materialize to offset high transportation costs. A gradual increase in the number of livestock is projected for the middle basin, many of which will be raised in newly constructed feedlot operations.

Significant increases in the cultivation of corn and soybeans are predicted for the lower basin, in addition to the production of market garden crops. A corresponding increase in irrigation on sandy and sandy loam soils may occur to increase row crop productivity. Tobacco will remain an important crop in the Whiteman and McKenzie creek basins.

4. WATER RESOURCES

4.1 Surface Water Quantity

The natural flow regime of the Grand river is highly variable. For example, a minimum 7-day flow at Cambridge (Galt) of 1.1 cubic metres per second (m^3/s) [37 cubic feet per second (cfs)] was recorded in August 1936 — a flow well below the level required to maintain adequate water quality. It was calculated that under natural flow conditions, a maximum instantaneous flow of 1,642 m^3/s (58,000 cfs) would have occurred at Cambridge (Galt) during April, 1975 but this flow was reduced by reservoir operations to about 852 m^3/s (30,100 cfs). Since major flooding occurs with flows greater than approximately 850 m^3/s (30,000 cfs), reservoir operations reduced the flow sufficiently to avoid significant flood damage.

To improve the water quality and reduce flooding problems created by fluctuating flow conditions, five multipurpose dams have been constructed: Shand (1942), Luther (1952), Conestogo (1958), Woolwich (1974), and Guelph (1976) (Fig. 2.1). These reservoirs are operated to reduce peak flows, particularly during the spring freshet. During the summer, stored water is released to augment low summer flows. The effects of the Luther, Woolwich and Guelph dams are mainly local on the upper Grand, Canagagigue and Speed rivers, respectively. The Shand dam, which created the Belwood reservoir, and the Conestogo dam have major impacts both locally and on the middle and lower Grand river.

The effect of existing reservoir operation on the flow regime of the middle Grand river is illustrated for a typical year (1977) at Cambridge (Galt). In 1977, reservoir operation caused a reduction in the spring flood peak from 1,190 m^3/s to 566 m^3/s (42,000 cfs to 20,000 cfs), thereby eliminating the threat of flooding (Fig. 4.1). Minimum flow targets were met by augmenting flows during a 120-day period between June and September (Fig. 4.2).

Flows would have fallen below the required minimum target of 11 m^3/s (400 cfs) on fifty-one days if there had been no flow augmentation. Flow augmentation from the existing reservoirs increases the river's self-purification abilities and thus the levels of dissolved oxygen in the central Grand river (Fig. 4.3). At a reach below Kitchener during the month of August, existing flow augmentation can increase the time that dissolved oxygen levels remain above a warm water fishery criteria of 4 mg/L, by about 20 percent over unregulated natural flow conditions.

During the summer months, the Shand and Conestogo dams currently are operated to maintain a river flow of 17 m^3/s (600 cfs) at Brantford and 11.3 m^3/s (400 cfs) at Doon. Reservoir yield analysis indicates that a river flow of 17 m^3/s (600 cfs) at Brantford and 9.9 m^3/s (350 cfs) at Doon can be maintained from May to October. As long as reservoir storage is available, it is possible to augment river flows into the winter months. Although winter river flows at Doon may drop as low as 1.4 m^3/s (50 cfs), flows normally remain above 2.8 m^3/s (100 cfs) from November to April.

CONESTOGO DAM AND RESERVOIR

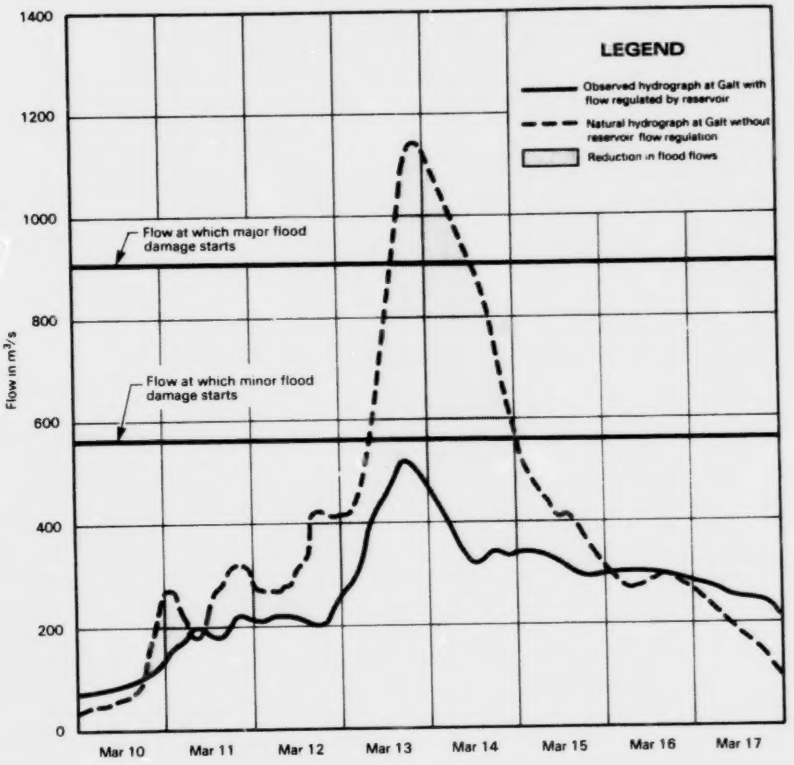


Figure 4.1. Effect of reservoir regulation upon 1977 flood flows, Grand River at Cambridge (Galt)

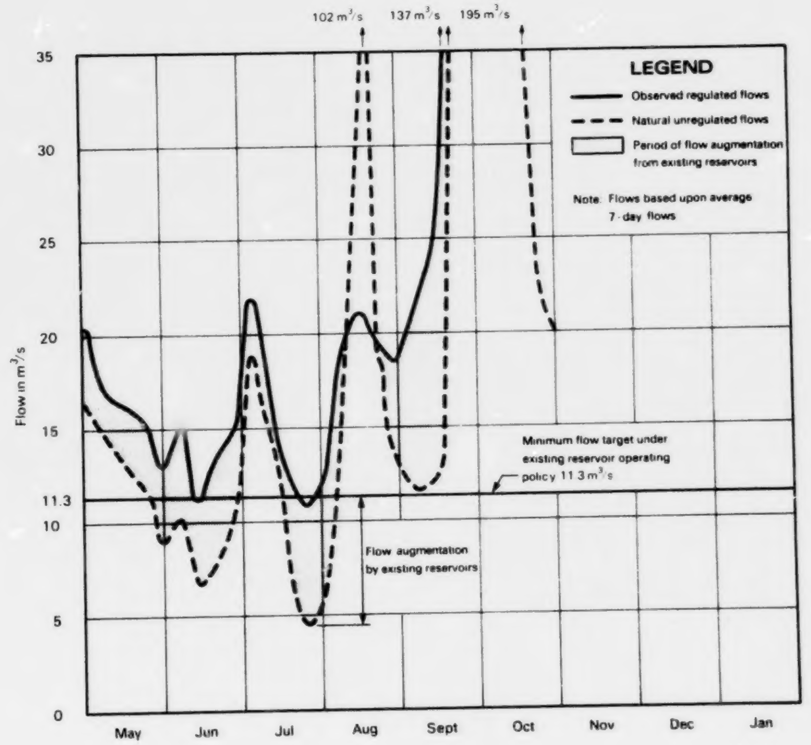
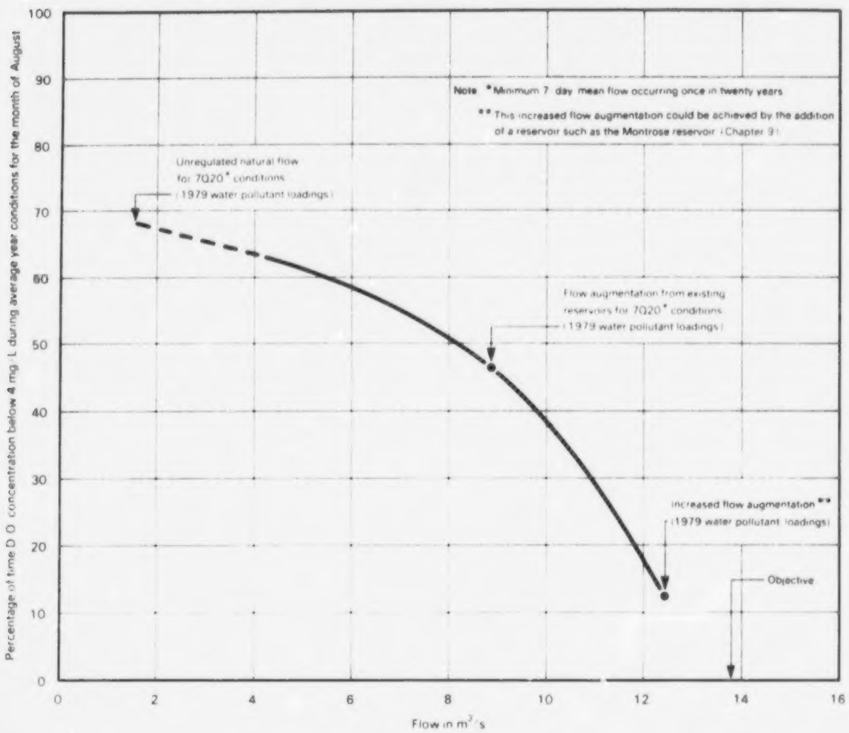


Figure 4.2. Effect of reservoir regulation on 1977 summer low flows, Grand River at Cambridge (Galt).

Average Year Conditions for the Month of August



Note: *Minimum 7 day mean flow occurring once in twenty years

** This increased flow augmentation could be achieved by the addition of a reservoir such as the Montrose reservoir (Chapter 9)

Figure 4.3. Effect of flow augmentation upon summer dissolved oxygen levels, Grand River at Blair (above confluence of Grand River and Speed River).

A comparison of the probability of obtaining summer flows under existing reservoir operations and under natural conditions is shown for the Grand river at Doon and Brantford, and the Speed river at Guelph (Fig. 4.4). It can be seen that existing reservoir operations significantly increase the probability of maintaining adequate flows at these locations.

4.2 Surface Water Quality

Surface water quality directly influences all of the major water uses of the Grand river and its tributary streams. Fish survival, diversity and growth; recreational activities such as swimming and boating; municipal, industrial and private water supplies; agricultural uses such as irrigation and livestock watering; waste disposal; and general aesthetics are all affected by the physical, chemical, biological and microbiological conditions which exist in the watercourse.

Water quality is influenced by natural conditions such as basin geology. This is observed in the lower Grand river which appears turbid — a condition which arises as the river flows through large clay plains and receives sediment. For the most part, serious pollution or use impairment in the Grand river is the direct result of human activities. Sources of pollution can generally be classified into two categories: point sources and non-point or diffuse sources.

Through investigations conducted as part of the basin study, the IJC-Pollution from Land Use Activities Reference Group (PLUARG) studies of the mid-1970s, and the surveillance programs of the Ministry of the Environment and the Grand River Conservation Authority, a great deal is known about water quality, use impairment and pollution sources throughout the basin.

In broad terms, it can be stated that water quality conditions in many areas of the basin are satisfactory and do not affect normal uses. Water quality impairment resulting from waste inputs from small municipalities and agricultural operations is usually localized, causing no use restrictions in downstream reaches. One problem which affects many basin watercourses is nutrient enrichment by phosphorus and the attendant problems of excessive aquatic plant and algae growth which, in turn, can affect fish and aquatic life habitat, municipal water supply and general aesthetics.

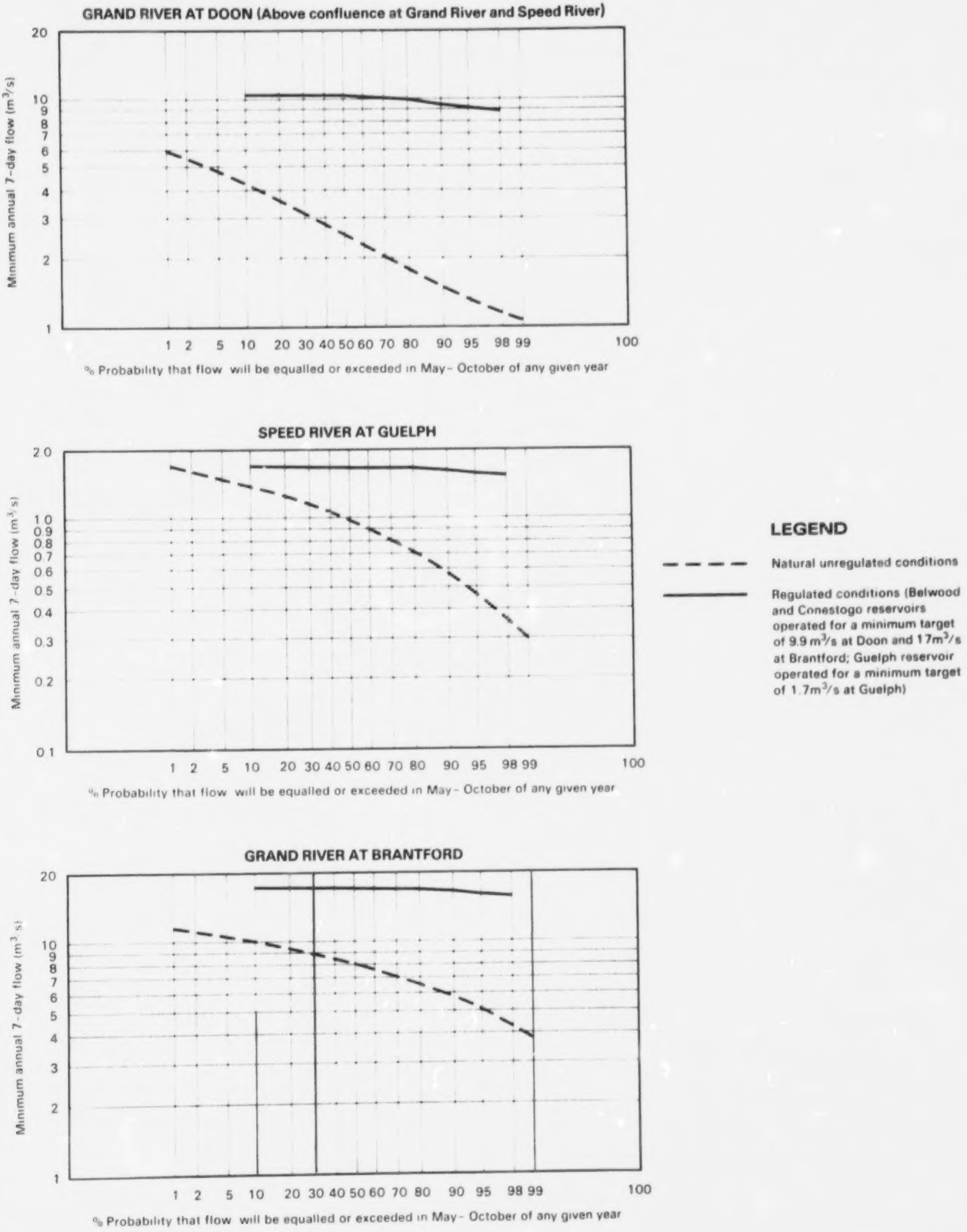


Figure 4.4. Frequency of summer flows at Doon, Guelph and Brantford (Minimum 7-day mean flow).

The most serious pollution problems in the basin are found in the vicinity of the municipalities of Waterloo, Kitchener, Cambridge and Guelph. These problems are very complex. Oxygen-demanding organic wastewater discharges from the municipal sewage treatment plants deplete the oxygen resources of the watercourse. Concurrently, nutrient inputs from the sewage treatment plants and non-point sources stimulate the growth of aquatic plants and algae which, through the photosynthesis-respiration process, produce large quantities of oxygen during the day and consume oxygen during the night. The combined effects of the organic waste demands and the diurnal cycling of dissolved oxygen, along with the physical choking of some river reaches by dense aquatic plant growths, render some sections of the river unsuitable habitats for fish and other desirable aquatic organisms. Further complications arise as fish, already under stress from low oxygen levels, become more susceptible to the toxic effects of other substances such as un-ionized free ammonia and heavy metals such as copper and zinc. These substances now marginally exceed the provincial water quality objectives for the protection of fish and aquatic life in the critical area of the river between Kitchener and Paris.

With respect to effects on humans, degraded water quality affects river aesthetics with unsightly accumulations of aquatic plants and with odours when oxygen resources are totally depleted or when aquatic plants decay. Bacterial contamination from sewage treatment plant discharges and land drainage create a potential risk to public health. Use of the river as a source of water supply can also be hampered or treatment costs substantially increased by the discharge of nutrients and a wide variety of compounds found in domestic and industrial wastes, urban stormwater drainage and rural non-point sources.

For example, although the growth of free-floating algae in the Grand river near the Brantford water works intake causes no serious water quality problems, it necessitates the city's use of activated carbon in its treatment process to forestall the possibility of taste problems. This additional treatment requirement substantially increases the annual water works operating costs. Nutrient enrichment, suspended particulates or trace contaminants could also affect the proposed ground water recharge scheme in the Regional Municipality of Waterloo by requiring costly treatment before the water is suitable for recharge into the ground water aquifer.

4.3 Ground Water Quantity

Ground water serves as a major source of supply for a variety of basin uses, ranging from low-capacity, private domestic household uses to high-capacity, industrial and municipal supplies. Ground water is found throughout the basin in bedrock formations and overburden materials. However, the variability in quantity and quality at different locations makes the problems of supply and demand complex.

Areas with various potential yields were mapped as part of the ground water investigations for the study (Ref. Tech. Report No. 10). Areas with yields less than 4 litres per second (L/s) [50 gallons per minute (gpm)] are generally not suitable for future exploration for large-scale municipal demands, but commonly meet private domestic requirements satisfactorily.

Ground Water In Bedrock

Ground water yields from bedrock in the northern part of the basin are judged to be up to 8 L/s (100 gpm), with scattered areas yielding over 15 L/s (200 gpm). In the central basin, anticipated yields exceed 15 L/s. South of Brantford, yields of less than 4 L/s (50 gpm) are expected. While high-yield areas in bedrock correspond mainly to areas of the Guelph and Amabel-Lockport formations which occur in the eastern half of the basin, a large area of probable yields greater than 15 L/s, is located in the Salina formation northwest of Kitchener-Waterloo (Fig. 4.5). In spite of the high yields likely from the Salina formation, much of the ground water is of poor quality and may not be acceptable for communal or private domestic purposes.

Ground Water In Overburden Materials

In overburden materials, ground water is readily available from sands and gravels which are sufficiently permeable to provide large amounts of water to wells. Where deposits are thick and extensive, aquifers capable of providing water in sufficient quantities to satisfy municipal needs are common. Ground water from most sand and gravel formations is of acceptable quality, with minimum treatment necessary for municipal uses.

Fine-grained sediments such as silts, clays and tills, although highly porous, are usually not permeable enough to yield water readily to wells.

Probable ground water yields in overburden north of Arthur and south of Brantford are less than 4 L/s (50 gpm) but are adequate for private domestic uses. Localized yields of greater than 15 L/s (200 gpm) are found in the central basin (Fig. 4.6). These high-yield areas currently supply the municipalities of Kitchener, Waterloo, Cambridge and Guelph and will be further utilized to meet expanding municipal needs.

4.4 Ground Water Quality

Water quality plays an important role in the development of ground water in the basin. Although water from bedrock and overburden in most areas is of acceptable quality for domestic uses, there are areas where ground water is of poor quality and water use is restricted.

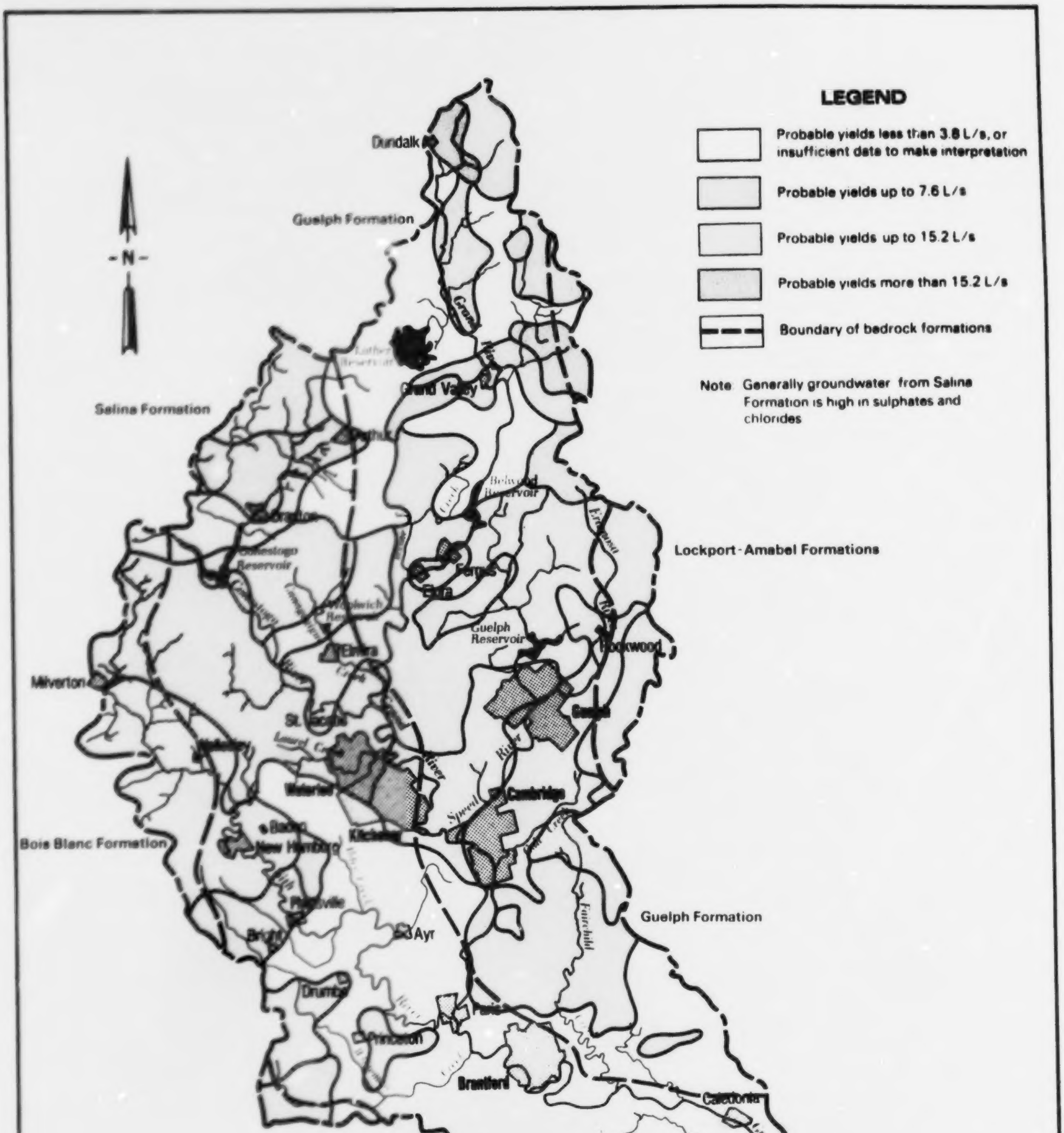

LEGEND
Probable yields less than 3.8 L/s, or insufficient data to make interpretation
Probable yields up to 7.6 L/s
Probable yields up to 15.2 L/s
Probable yields more than 15.2 L/s
Boundary of bedrock formations
Note: Generally groundwater from Salina Formation is high in sulphates and chlorides
N
Dundalk
Guelph Formation
Luther Reservoir
Grand Valley
Salina Formation
Arthur
Drayton
Conestogo Reservoir
Woolwich Res.
Belwood Reservoir
Lockport-Amabel Formations
Fergus
Elora
Elmira
Guelph Reservoir
Rockwood
Milverton
St. Jacobs
Guelph
Waterloo
Cambridge
Kitchener
Baden
New Hamburg
Bois Blanc Formation
Plattsville
Bright
Ayr
Guelph Formation
Drumbo
Paris
Princeton
Brantford
Caledonia
Grand River
Salina Formation
Hagersville
Cayuga
Bois Blanc Formation
Dunnville
0 5 10 20 30 Kilometres
LAKE ERIE

Figure 4.5. Ground water yields from bedrock.

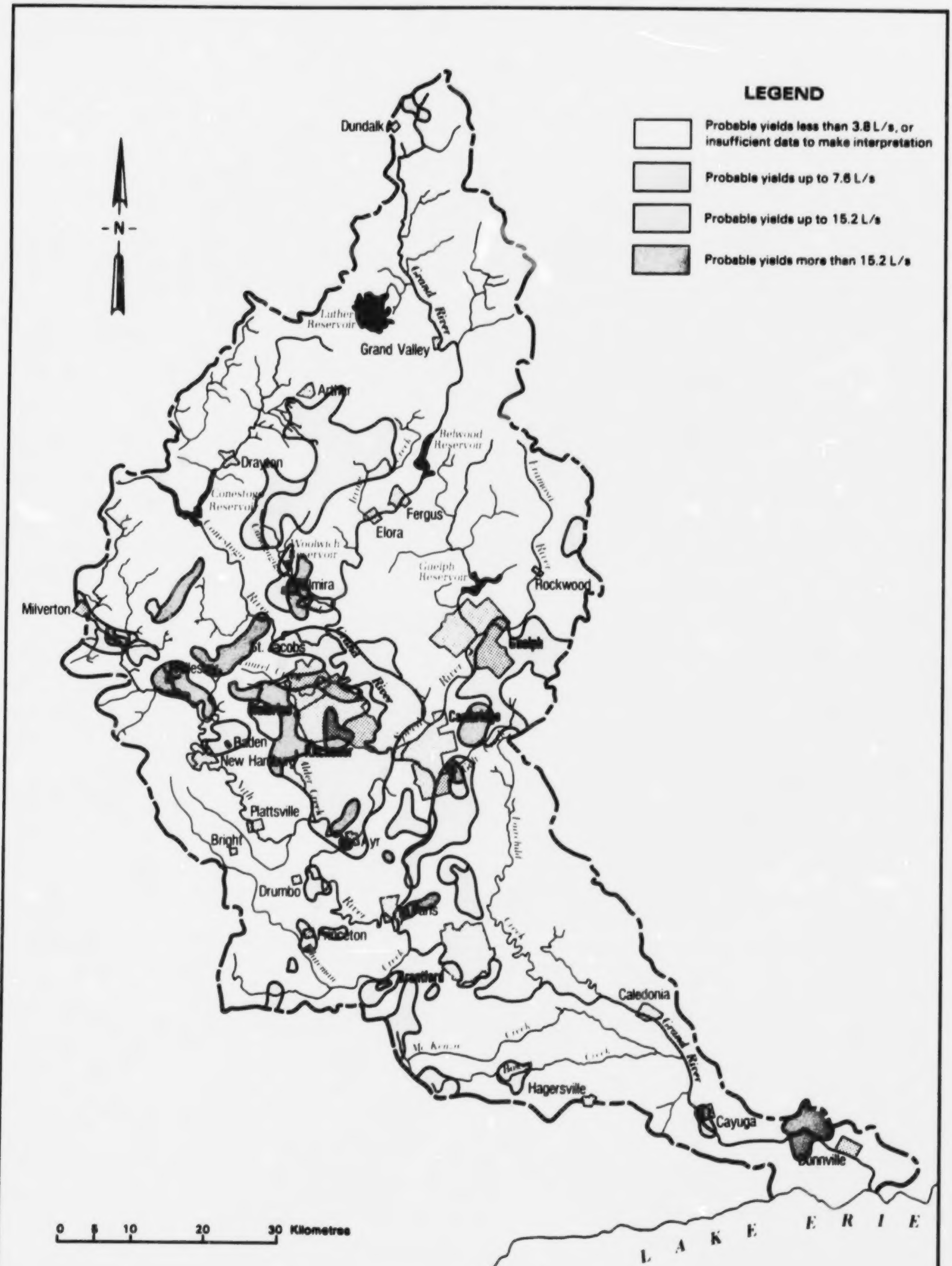

LEGEND
Probable yields less than 3.8 L/s, or insufficient data to make interpretation
Probable yields up to 7.6 L/s
Probable yields up to 15.2 L/s
Probable yields more than 15.2 L/s
N
0
5
10
20
30
Kilometres
Dundalk
Luther Reservoir
Grand River
Grand Valley
Arthur
Belwood Reservoir
Drayton
Conestogo Reservoir
Conestogo
Fergus
Elora
Woolwich Reservoir
Guelph Reservoir
Elmira
Rockwood
Milverton
St. Jacobs
Guelph
Cambridge
Baden
New Hamburg
Nith
Plattsville
Bright
Ayr
Drumbo
Paris
Princeton
Brantford
Caledonia
McKenzie
Creek
Hagersville
Cayuga
Dunnville
LAKE ERIE

Figure 4.6. Ground water yields from overburden.

Ground water quality is related to the geology of the medium through which the water passes. The hydrochemistry of water in bedrock in the Grand river basin is related to the three main bedrock formations — the Salina, the Guelph and the Amabel-Lockport formations. The Salina formation is composed of limestones, dolomites, shales, and evaporite deposits consisting of anhydrite, gypsum and salts. When ground water moves through these deposits, dissolution of the various minerals occurs. This process produces high levels of total dissolved solids in water from the Salina formation. The Guelph and Amabel-Lockport formations are composed mainly of limestones and dolomites, which consist predominantly of calcite ($CaCO_3$) and dolomite ($CaMg(CO_3)_2$). As ground water moves through these formations, dissolution of calcite and dolomite occurs. This process results in lower levels of total dissolved solids in the ground waters of the Guelph and Amabel-Lockport formations than in those of the Salina formation.

Ground water in bedrock in the northern and eastern portions of the basin (corresponding to the Guelph and the Amabel-Lockport formations) is of calcium-bicarbonate type, has moderate concentrations of total dissolved solids and is generally very hard. Ground water in the western and southern portions of the basin (corresponding to the Salina formation) is of calcium-sulphate type, is very hard, and has high concentrations of total dissolved solids in excess of the permissible level, with the highest levels occurring in wells developed in the Salina formation.

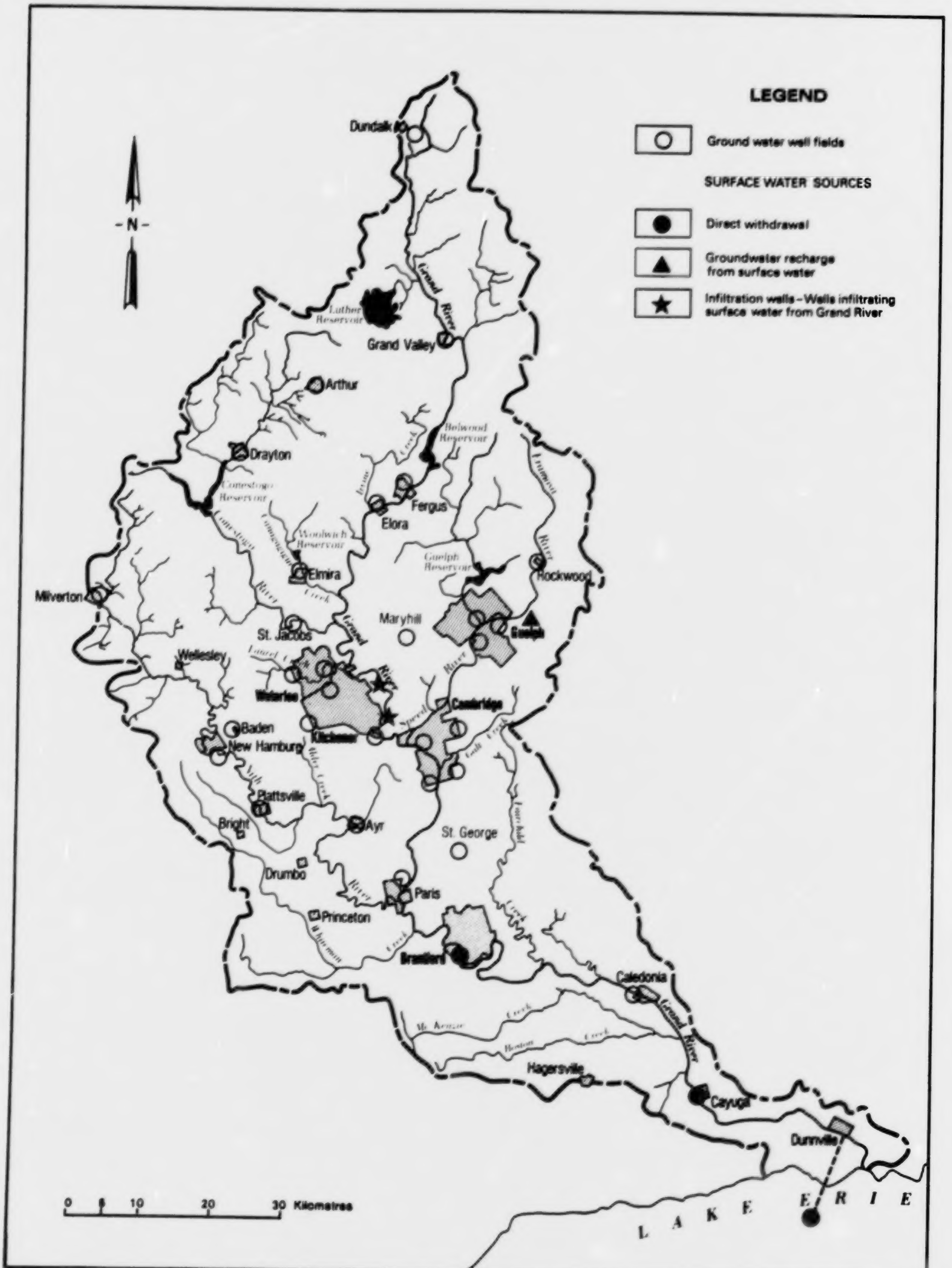

LEGEND
○ Ground water well fields
SURFACE WATER SOURCES
● Direct withdrawal
▲ Groundwater recharge from surface water
★ Infiltration wells – Wells infiltrating surface water from Grand River
N
0 5 10 20 30 Kilometres
Dundalk
Grand River
Luther Reservoir
Grand Valley
Arthur
Belwood Reservoir
Irvine Creek
Eramosa River
Drayton
Conestogo Reservoir
Conestogo River
Canagagigue Creek
Woolwich Reservoir
Fergus
Elora
Guelph Reservoir
Rockwood
Elmira
Milverton
Maryhill
Guelph
St. Jacobs
Wellesley
Laurel Creek
Speed River
Waterloo
Cambridge
Kitchener
Baden
New Hamburg
Nith River
Alder Creek
Galt Creek
Plattsville
Ayr
Bright
St. George
Fairchild Creek
Drumbo
Paris
Princeton
Whiteman Creek
Brantford
Caledonia
McKenzie Creek
Boston Creek
Hagersville
Cayuga
Dunnville
LAKE ERIE

Figure 5.1. Sources of municipal water supply.

5. WATER USES

The water resources of the Grand river basin are used for a wide variety of purposes including water supply, waste disposal, recreation, and fish and wildlife habitat (Tables 5.1 and 5.2). Estimates of existing water use in the basin are described in the following sections.

5.1 Water Supply

5.1.1 Municipal

The greatest consumptive use of water in the basin is for urban and rural domestic purposes. An average of 240,915 cubic metres per day (m^3/d) [(53 million gallons per day) (mgd)] is required to meet the municipal water needs of the urban population. Of this amount, 22 percent is supplied from surface water and 78 percent from ground water (Fig. 5.1). The remainder of the basin population uses approximately 25,455 m^3/d (5.6 mgd) from ground water sources for rural domestic purposes.

Almost 90 percent of the municipal water demand occurs in the urban centres of Kitchener, Waterloo, Cambridge, Guelph and Brantford. With the exception of Brantford, this concentrated demand relies mainly on ground water supplies.

5.1.2 Industrial

Although water consumption data for industries obtaining water from municipal sources have not been compiled separately, it was estimated that in 1978, an average of 30 percent of municipal water consumption in the major urban centres is for industrial service. In addition, industries not connected to a municipal water supply system withdrew about 145,458 m^3/d (32 mgd) which represents a substantial proportion of the total basin water withdrawals. Most of the industrial water needs provided by non-municipal sources occur in the middle and lower parts of the basin.

Over 60 percent of the water withdrawn directly for industrial use is obtained from ground water sources including wells and dugout ponds. Uses, in order of decreasing amounts of water withdrawn, include washing aggregates and dewatering gravel pits, industrial cooling, food processing and industrial processing, pollution control, and miscellaneous purposes. Water used in aggregate processing is generally discharged to settling ponds and eventually returned to the ground water system through natural seepage or to streams, while water used for industrial cooling and processing by manufacturers is generally discharged to existing municipal sewer systems.

WATER TREATMENT PLANT AT BRANTFORD: Water is supplied from the Grand river

Table 5.1 Existing Urban and Rural Water Uses
(cubic metres per day x 1000)

Sub-basin	Irrigation Crops/Sod 1978	Livestock 1976	Municipal 1978	Rural Domestic 1978	Industrial 1978-79	Commercial 1978	Recreational 1978	Irrigation Golf 1978	Total
Lower Grand River	147.03 + 1 storage pond	5.75	7.01	6.45	44.38	1.51	13 storage ponds	1.78	213.91
Whiteman Creek	244.28	2.02	--	1.58	0.49	--	1 storage pond	--	248.37
Nith River	40.88	8.60	67.18	4.70	18.16	--	0.10 + 17 storage ponds	0.55	140.17
Paris and Middle Grand River	10.21	7.47	163.95	8.02	70.21	7.33	10.70 + 28 storage ponds	7.57	285.46
Conestogo River	--	8.01	1.91	3.16	13.95	--	3 storage ponds	--	27.03
Upper Grand River	--	3.14	.16	1.46	--	--	3 storage ponds	--	4.76
Total Estimated Withdrawal Rate* (m^3/d x 1000)	442.40	34.99	240.21	25.37	147.19	8.84	10.80	9.90	919.70
Percent of Total Estimated Withdrawal Rate	48.1%	3.8%	26.1%	2.8%	16.0%	0.9%	1.2%	1.1%	100%
Total Estimated Annual Withdrawal Volume** (m^3 x 1000)	2,211.99	12,772.02	87,678.31	9,262.92	38,297.13	3,042.68	647.69	792.45	154,705.19
Percent of Total Estimated Withdrawal Volume	1.4%	8.3%	56.7%	6.0%	24.8%	1.9%	0.4%	0.5%	100%

Note: 1 million gallons per day (mgd) = 4546 cubic metres per day (m^3/d)

* The irrigation rates are used only for short periods of time during the summer months.

** These are annual volumes based on the duration and rate of use during the year.

Table 5.2 Existing Recreational Water Uses

Use Sub-basin	Fishery		Aesthetics	Body Contact Recreation	Boating
	Warm	Cold			
Lower Grand River	major	moderate	moderate-major	major	major
Whiteman Creek	minor	minor	major	minor	minor
Nith River	moderate	minor	moderate	minor	minor
Paris	moderate	minor	major-moderate	minor	minor
Middle Grand River	moderate	minor	major-moderate	moderate	minor
- Grand River	major	minor	moderate	minor	minor
- Speed River	moderate	moderate	moderate-major	minor	minor
- Eramosa River	moderate	moderate	major	moderate	minor
- Guelph Reservoir	major	minor	major	major	major
Conestogo River	moderate	minor	moderate-minor	minor	minor
- Conestogo Reservoir	moderate	moderate-minor	major	major	major
Upper Grand River	minor	minor	major	minor	minor
- Luther Marsh	moderate-minor	minor	major	minor	minor
- Belwood Reservoir	moderate-major	minor	major	major	major

The remaining industrial supply is obtained from surface water and is used mainly for mineral extraction and processing (sand, gravel, limestone). The waste is usually discharged to settling ponds and returned to the surface water source. On the average, approximately 1 percent of the total volume of water used is lost through evaporation during an eight month operation period between April and November.

5.1.3 **Agricultural**

Within the Grand river basin, water is used for two main agricultural purposes: watering livestock and irrigating crops.

Based on the number of livestock in the basin, the amount of water used in 1976 for livestock consumption was estimated to be about 35,000 m^3/d (7.7 mgd). Water supplies for feedlot and poultryfarm operations are primarily obtained from wells. Pastured cattle and mixed herds on small farms are watered from a variety of sources, including streams, ponds, springs, and drilled or dug wells. The largest livestock demands occur in the basins of the middle Grand and Nith rivers.

Water use for farm crop irrigation occurs between the months of June and August. Considerable areas of tobacco and some market garden crops requiring irrigation are grown on the sandy soils in the watersheds of Whiteman, Mt. Pleasant and McKenzie creeks. As of 1979, the Ontario Ministry of the Environment authorized a maximum water withdrawal rate for irrigation of about 442,400 m^3/d (97 mgd) with 88 percent of this amount from surface water sources. Actual water withdrawals are generally much less than those permitted by the Ministry. Studies indicate that, on the average, approximately 25 percent of the authorized withdrawals for irrigation occur simultaneously. The most intensive irrigation occurs in a relatively short time period when the crops are nearing maturity. At present, tobacco is the crop most commonly irrigated. Irrigation water demands tend to coincide with the period of lowest water availability in streams and therefore represent a significant potential impact on the surface water regime.

5.1.4 **Summary of Water Supply Uses**

The total known withdrawal uses in the basin range from a yearly average of 456,600 m^3/d or 5 m^3/s (100 mgd) to a daily maximum of 919,700 m^3/d or 10 m^3/s (202 mgd) during the summer months assuming maximum simultaneous withdrawal for irrigation and recreational uses (Table 5.1; and Ref. Tech. Report No. 26).

5.2 **Waste Assimilation**

Water bodies such as the Grand river have the ability to accept and assimilate a certain amount of oxygen-demanding wastes and other biodegradable wastes. However, if too much organic material is discharged, oxygen resources may become severely depleted leaving insufficient oxygen for fish and other organisms. Thus, there is need for a balance between waste discharged into a river and the river's ability to safely absorb these wastes. The following sections describe the municipal, industrial and agricultural sources of pollution which affect the Grand river system.

5.2.1 **Municipal Wastes**

In 1980, over 80 percent of the urban basin population was serviced by wastewater treatment systems discharging to the Grand river and its tributaries. The remainder of the population used septic tanks and tile field systems (Fig. 5.2).

All major municipalities in the basin are served by sewage treatment systems which provide biological secondary treatment of wastes. Such systems are designed to remove more than 90 percent of the suspended solids and oxygen-consuming organic materials [expressed as 5 day biochemical oxygen demand (BOD_5)], but they remove very little organic nitrogen and ammonia. Guelph is served by an advanced sewage treatment facility which provides an effluent with very low levels of BOD, suspended solids, organic nitrogen and ammonia. Sewage treatment plants at Waterloo, Kitchener, Guelph, Cambridge and Brantford, contribute over 77 percent of the total treated effluent, with an average of 280,770 m^3/d or 3 m^3/s (62 mgd) discharged to the river system (Appendix E).

All of the major municipalities have separate systems for stormwater runoff and sanitary sewage. Pollution loads from urban stormwater drainage empty directly into the Grand or Speed rivers or to local watercourses. The urban runoff generally has little effect on receiving streams that have large summer flows, such as the Grand or Speed river, but can cause significant problems to small local watercourses such as Schneider creek in Kitchener or Hanlon creek in Guelph where summer flows periodically fall to below 0.03 m^3/s (1 cfs).

5.2.2 **Industrial Wastes**

Most industries in the basin discharge wastes to local sewer systems for treatment at municipal sewage treatment facilities. Sewer use by-laws are enforced by municipalities to ensure that industrial wastes discharged to sewers are not toxic or corrosive.

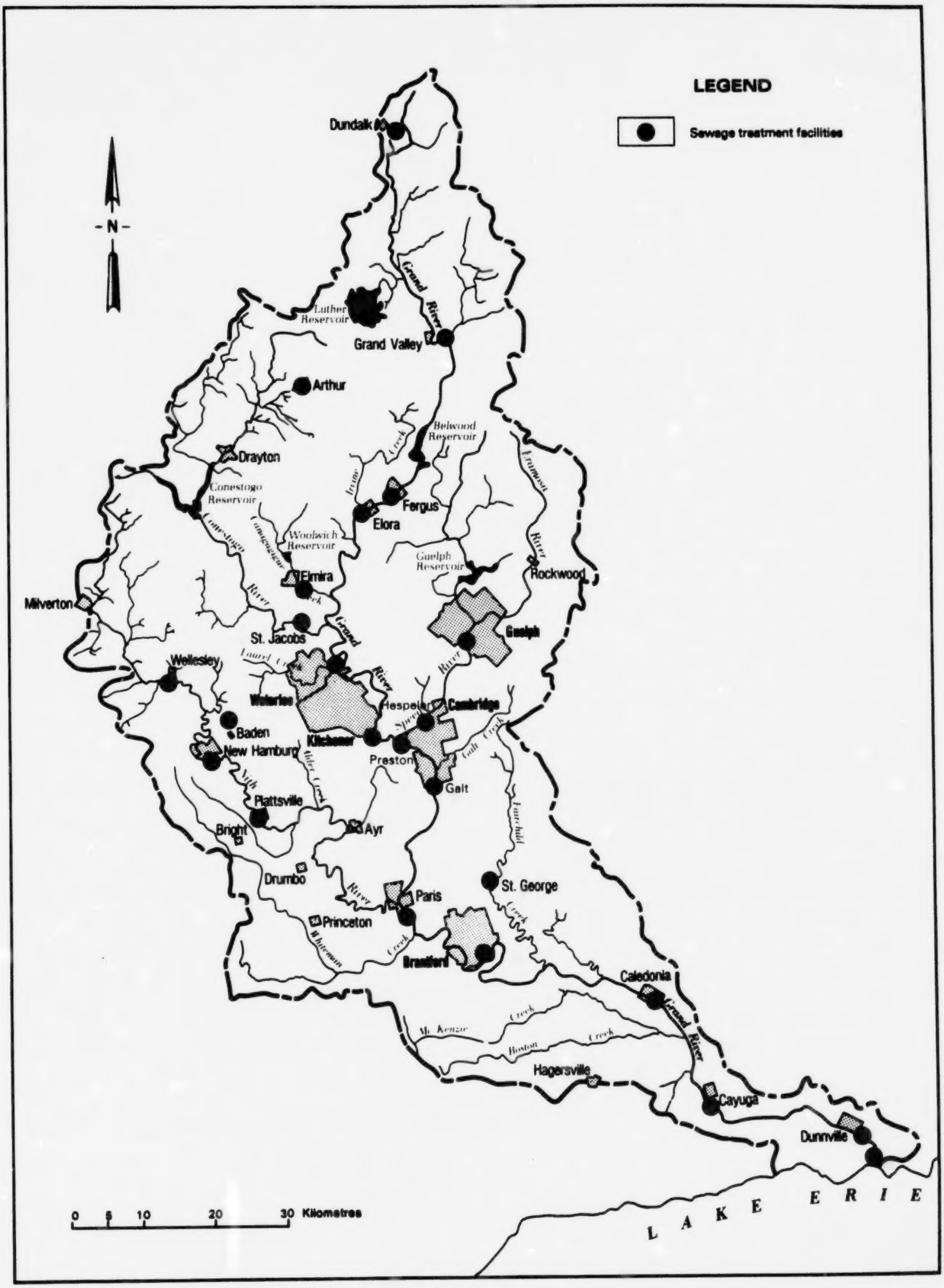
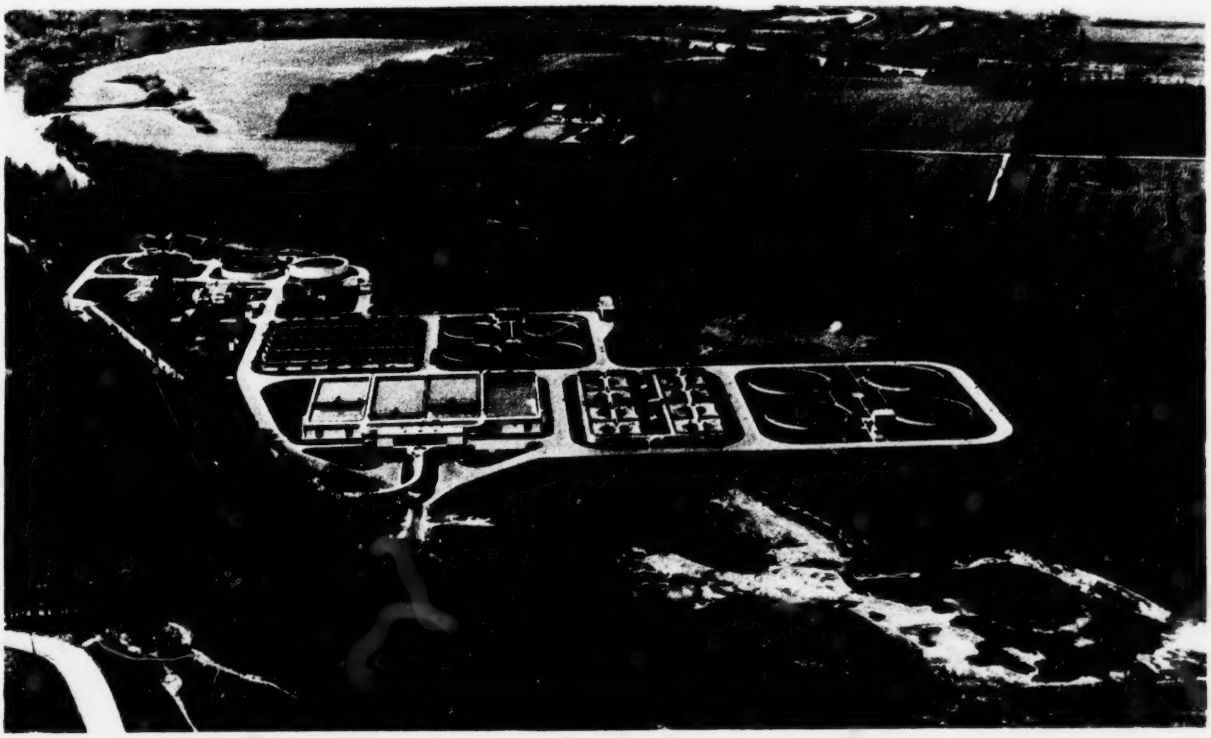

LEGEND
● Sewage treatment facilities
N
Dundalk
Luther Reservoir
Grand River
Grand Valley
Arthur
Belwood Reservoir
Irvine Creek
Drayton
Conestogo Reservoir
Fergus
Elora
Eramosa River
Woolwich Reservoir
Canagagigue Creek
Conestogo River
Guelph Reservoir
Rockwood
Elmira
Milverton
St. Jacobs
Guelph
Laurel Creek
Wellesley
Waterloo
Hespeler
Cambridge
Speed River
Baden
Kitchener
Preston
New Hamburg
Nith
Alder Creek
Galt Creek
Galt
Plattsville
Fairchild
Bright
Ayr
Drumbo
St. George
Paris
River
Creek
Princeton
Whiteman
Brantford
Caledonia
Mc Kenzie Creek
Boston Creek
Hagersville
Cayuga
Dunnville
LAKE ERIE
0 5 10 20 30 Kilometres

Figure 5.2. Location of municipal sewage treatment plants.



KITCHENER SEWAGE TREATMENT PLANT: This is a modern conventional activated sludge sewage treatment plant. This plant discharges its effluent into the Grand river (in background)

If corrosive or toxic wastes are produced, the industry is required to reduce harmful waste characteristics to acceptable limits prior to discharge to the sewer system. In some municipalities such as Brantford and the Regional Municipality of Waterloo, the industry pays a surcharge to the municipality to compensate for municipal treatment of high strength wastes. The majority of industrial wastes discharged to sewers do not create problems, although a few problems have been encountered with industries located in St. Jacobs, Fergus, Elmira and Paris (Appendix E).

Of the over 1,000 manufacturing plants in the basin, only 7 produce a substantial waste effluent which is discharged directly to the river following chemical or biological treatment by the firm. A total of 43,750 m^3/d or 0.5 m^3/s (9.6 mgd) of wastewater is produced by these industries and this represents approximately 16 percent of the total treated effluent discharged to the Grand river (Appendix E).

5.2.3 Agricultural Wastes

The chief sources of suspended solids, nitrogen, phosphorus, oxygen-demanding wastes and bacterial pollutants from agriculture, result from livestock operations and field applications of manure. Waste disposal from livestock operations generally takes place on land and only through poor management practices do significant amounts of waste materials gain access to watercourses. With a trend in the middle basin towards more feedlot operations where livestock is raised in confined areas, the potential for animal waste materials to gain access to watercourses is increased unless precautions are exercised. To a limited extent, pesticides applied to agricultural lands gain access to the basin's watercourses. With the exception of accidental spills or poor management practices causing local degradation, levels of pesticides in the Grand river are low and do not impair existing uses.

STORAGE OF LIVESTOCK WASTES: Prevents pollution of nearby watercourses.

5.3 Water-Based Recreation

Water-based recreation covers a wide variety of activities undertaken by people in or on water as well as on land adjacent to water bodies. Analysis of Ontario Recreation Survey data compiled by the Ontario Ministry of Natural Resources indicates that among Ontario residents, top-ranked recreational pursuits include swimming, camping, picnicking, canoeing and fishing.

The Grand river basin provides a variety of water-based recreational opportunities* on both publicly and privately-owned lands. Information regarding the location and type of water-based activities pursued in the basin was obtained from the Ministry of Natural Resources (Recreation Supply Inventory), the Grand River Conservation Authority and recreation clubs. Based on these data, the estimated numbers of opportunities in the basin are 3,059,000 for picnicking, 2,029,000 for camping, and 2,410,000 for swimming. The Grand River Conservation Authority is a principal operator of water-based recreational facilities providing opportunities for swimming, camping, picnicking, boating, sailing and hiking, particularly at reservoir sites such as Conestogo, Belwood, Laurel Creek, Shade's Mills, Rockwood and Guelph. Most of the water-based recreational facilities are clustered in the central portion of the watershed where 60 percent of the picnicking, 65 percent of the camping and 26 percent of the swimming opportunities are available. Approximately 69 percent of the swimming opportunities are located in the lower region of the watershed, most of which are along the Lake Erie shoreline.

The watershed also provides opportunities for water skiing and boating, particularly in the lower reaches and for canoeing in tributaries and stretches along the main Grand river, south of Grand Valley to Lake Erie. The Grand river fishery resource is significant for its recreational value. Warm-water sport fish, particularly bass, are caught in various stretches along the main Grand and its major tributaries, and cold-water fish such as trout are fished in tributary headwaters. Cold-water fish are also sought in the Grand river south of Brantford when the fall spawning runs of Lake Erie coho salmon and steelhead trout take place. Minimum estimates of the participation of anglers are approximately 200,000 angler days per year with a potential of 575,000 angler days per year. Studies of the average amount of money spent per angler day indicate that the annual value of the fishery in these terms, at present, is well over $1 million.

SAILING ON THE CONESTOGO RESERVOIR

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* *A recreational opportunity is a unit of measurement used to calculate recreation supply. Participation by an individual in an activity for any length of time during a day is considered to be an occasion of that activity. The number of opportunities of an activity provided by a facility or resource over a specified time period is equal to the number of occasions that they can accommodate (Ref. 4).*

Table 5.3
Presence (X) of Common Fish Species in Reaches of the Main Grand River

Species / Reach	Salmonids		Warm-Water Sport Fish									Coarse Fish	
	Rainbow Trout	Coho Salmon	Walleye	Northern Pike	Smallmouth Bass	Largemouth Bass	Rock Bass	Yellow Perch	Sunfish	White Crappie	Black Crappie	Common White Sucker	Carp
Upper Basin — Belwood Lake Area	X			X			X	X	X			X	X
Fergus-Elora Area							X	X	X			X	X
Conestogo-Bridgeport Area				X	X		X	X	X			X	X
Waterloo-Kitchener				X	X		X	X	X			X	X
Preston-Galt Area				X	X		X	*	X			X	X
Glen Morris Area				*	X	X	X	*	X			X	X
Paris Area			X	X	X	*	X	X	X			X	X
Brantford		*	X	X	X	X	X	*	X		X	X	X
Caledonia Area	X	X	X	X	X	X	X	*	X	X	*	X	X
Dunnville Area	X	X	X	X	X	X	X	X	X	X	X	X	X

* Fish not caught during survey but there is a strong likelihood they are present in this reach.

Table 5.4
Presence (X) of Common Fish Species in Reaches of the Speed and Eramosa Rivers

	Species / Reach	Salmonids	Warm-Water Sport Fish							Coarse Fish	
		Brook Trout	Smallmouth Bass	Largemouth Bass	Pumpkinseed	Bluegill	Rock Bass	Green Sunfish	Longear Sunfish	Common White Sucker	Carp
Upper	**SPEED RIVER** First bridge downstream Shiloh	X								X	
	First bridge west of Hwy. 24 on Eramosa and Guelph Twp. Line		X				X			X	
Guelph	Downstream Hanlon Pkwy.		X	X			X	X		X	X
Below Guelph	Below Kortright Waterfowl Park						X			X	X
Hespeler	Mill Pond		X				X			X	X
Preston	Where Hwy. 8 crosses Speed river outside of Preston		X				X	X	X	X	X
	ERAMOSA RIVER Cedar Valley	X								X	
	Hwy. 25 south of Ospringe	X								X	
	In Rockwood Park						X				
	1st Line of Eramosa Twp.					X	X			X	
	1st Line of Guelph Twp.		X	X	X					X	

5.4 Fish and Wildlife

Most of the Grand river and its major tributaries support a warm-water fishery. Consequently, the fish commonly associated with this type of environment, particularly three families of fish — pike, perch and sunfish — are the most abundant. The lower Grand river provides the most diverse habitat in the basin and supports over fifty species of fish.

Cold-water species such as brook trout are resident in source areas of such tributaries as McKenzie creek and the Speed and Eramosa rivers. The cold-water fishery from Brantford to Lake Erie is represented by the fall spawning runs of coho salmon and steelhead trout.

South of Paris, along the Grand river, those fish most commonly caught are pickerel, pike and smallmouth bass. In 1976, a creel census conducted in the central basin revealed that 22 percent of the sport fish caught (of 11 species) were smallmouth bass. Approximately 60 percent of the anglers surveyed were fishing for a specific species of fish (bass or pike). Tables 5.3 and 5.4 indicate the types of fish found in various regions of the Grand, Speed and Eramosa river basins.

The Grand river basin provides habitat for a wide diversity of wildlife. Waterfowl breeding and stop-over areas are abundant throughout the basin with the major areas being the Luther marsh, Conestogo reservoir, Salem forest, Eramosa river valley, Drumbo swamp, Beverly swamp, Phillipsburg forest, Oakland swamp, Taquanyah reservoir and Dunnville marsh. Many species of birds and mammals are common throughout the basin, their habitats delineated and protected in some areas by municipal legislation. Fur-bearing animals are trapped in some areas. Those species which constituted over 95 percent of the $110,502 received in 1975 by trappers include raccoon, fox, muskrat, beaver and mink (Ref. 5).

6. WATER RESOURCE PROBLEMS

Three significant water resource problems have been identified in the Grand river basin: (1) water shortages; (2) flood damages; and (3) deteriorated water quality. The subsequent sections provide details on these problems.

6.1 Water Supply

6.1.1 Objective

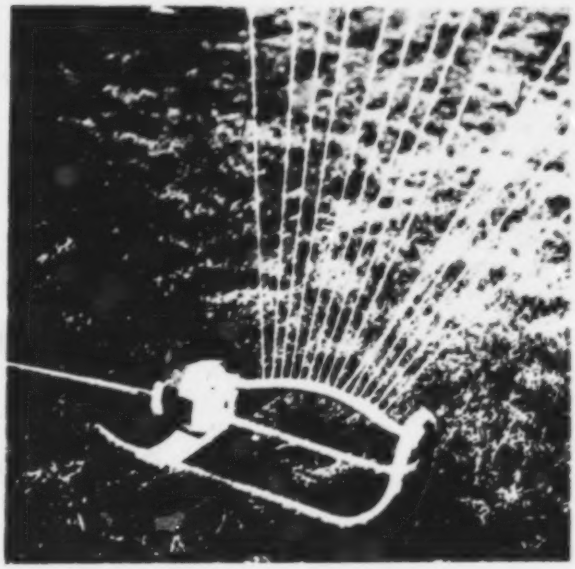
One objective of the basin study is to ensure an adequate supply of high quality water for future municipal, industrial and agricultural needs within the Grand river basin. This objective encompasses demand and supply and requires solutions that deal with both.

Withdrawals of surface and ground water for various water needs are controlled by the Ontario Ministry of the Environment through a permit system. Development of water supplies is the responsibility of municipalities, industries, and individuals and the actions of one may affect the supplies of others. As well, the quality of surface and ground water supplies must be maintained to ensure their continuing suitability for consumption. This is of paramount importance in the Grand river basin where the contamination of local surface and ground water sources could affect existing water supplies, making them unsuitable for consumption.

6.1.2 Problems

As of 1980, no serious water shortages had occurred in the basin. However, in the Regional Municipality of Waterloo, the existing ground water sources are being utilized to their maximum capacity during periods of high summer demand. In the future, it will be necessary to provide additional supplies to the municipalities of Kitchener, Waterloo and Cambridge.

Attendant with water shortage problems is the problem of large municipal wells lowering water levels in rural domestic wells and reducing flows in surface streams. Most well interference problems are associated with the Kitchener-Waterloo area, and a smaller number are associated with wells in the Cambridge and Guelph areas. All valid water level interference problems have been resolved, usually by deepening existing wells or constructing new ones under requirements of the Permit to Take Water program administered by the Ontario Ministry of the Environment. Future ground water development may create additional interference problems. In particular, the development of new ground water supplies in the vicinity of Cambridge may potentially interfere with nearby ground water supplies and stream flows in the Galt creek area.



A SUMMER WATER USE: Lawn sprinkling causes high peak municipal water demands during the summer.

The selection and timing of new water supply projects will be influenced by future water demands. Reductions of water demand through the use of water conservation measures can defer the need for major supply projects from five to ten years. Because of the excellent service provided by the municipalities and public utilities, supply is often taken for granted. This is evidenced by the results of some public perception surveys. One, completed as an early part of the public consultation program, indicated that maintaining adequate water supply was a lower priority than water quality or flooding. After being informed of basin water supply and demand problems, the public consultation working groups ranked water supply the most important water management problem.

The following sections compare anticipated municipal, industrial and agricultural water requirements to the year 2031 with water supplies and indicate what needs to be done to meet future water demands.

6.1.3 Municipal Water Requirements

Municipal water demand varies throughout the year with maximum water demands occurring during the summer months when lawn watering is at a maximum. This variation in demand is characterized by average and maximum day demands.

The maximum day demand is a short-term demand which is usually met by: (1) increasing the pumping rate from ground water storage, (i.e. Kitchener, Waterloo), and (2) increasing the pumping rate from surface storage or surface sources, (i.e. Brantford).

Table 6.1
Additional Municipal Water Supply Necessary to Meet Average Day Projected Demand*, 2001 and 2031

(cubic metres per day x 1000)

Water Demand Projections / Community	2001							2031						
	Base Case***			Price Sensitive Medium Population		Water Conservation Medium Population		Base Case			Price Sensitive Medium Population		Water Conservation Medium Population	
	Low Population	Medium Population	High Population	High Demand Curve	Low Demand Curve	Moderate Response	Maximum Response	Low Population	Medium Population	High Population	High Demand Curve	Low Demand Curve	Moderate Response	Maximum Response
Kitchener-Waterloo System Capacity - 148.40														
Avg. Day Demand - 68.80 (1978)	143.78	153.19	159.41	139.32	129.91	137.46	121.32	158.19	219.87	251.23	208.19	187.91	191.73	167.96
Additional Supplies Needed	--	4.79	11.01	--	--	--	--	9.79	71.47	102.83	59.79	39.51	43.33	19.56
Guelph System Capacity - 117.32														
Avg. Day Demand - 43.18 (1978)	54.96	70.32	79.46	70.32	62.46	57.18	50.36	74.09	126.41	165.46	135.96	113.14	86.50	73.18
Additional Supplies Needed	--	--	--	--	--	--	--	--	9.09	48.14	18.64	--	--	--
Brantford** System Capacity - 79.55														
Avg. Day Demand - 43.96 (1978)	55.86	61.82	68.37	65.50	57.73	50.50	46.46	74.73	93.37	116.59	103.00	87.87	66.59	59.73
Additional Supplies Needed	--	--	--	--	--	--	--	--	13.82	37.04	23.45	8.32	--	--
Cambridge System Capacity - 77.23														
Avg. Day Demand - 38.99 (1978)	64.23	68.46	71.23	62.82	57.73	56.59	49.23	70.68	98.27	113.00	92.59	82.82	75.55	64.96
Additional Supplies Needed	--	--	--	--	--	--	--	--	21.04	35.77	15.36	5.59	--	--

* Refers to supplies which would be necessary to meet demand after the 1979 source capacity is fully utilized.

** Demand for the City of Brantford is expected to be met wholly through extraction of river water.

*** Refer to Table 3.1 for population projections.

Note: 1 million gallons per day (mgd) = 4546 cubic metres per day (m^3/d)

Table 6.2
Additional Municipal Water Supply Necessary to Meet Projected Maximum Day Demand*, 2001 and 2031
(cubic metres per day x 1000)

Water Demand Projections / Community	2001							2031						
	Base Case***			Price Sensitive Medium Population		Water Conservation Medium Population		Base Case			Price Sensitive Medium Population		Water Conservation Medium Population	
	Low Population	Medium Population	High Population	High Demand Curve	Low Demand Curve	Moderate Response	Maximum Response	Low Population	Medium Population	High Population	High Demand Curve	Low Demand Curve	Moderate Response	Maximum Response
Kitchener-Waterloo System Capacity = 148.40														
Max. Day Demand = 132.20 (1978)	213.79	227.39	235.56	223.27	194.84	199.38	180.37	233.30	314.06	348.10	332.78	280.51	270.95	243.03
Additional Supplies Needed	65.39	78.99	87.16	74.87	46.44	50.98	31.97	84.90	165.66	199.70	184.38	132.11	122.55	94.63
Guelph System Capacity = 117.32														
Max. Day Demand = 59.55 (1978)	94.77	119.64	134.05	112.32	118.09	96.05	88.18	124.41	204.37	262.46	217.69	202.50	142.59	126.41
Additional Supplies Needed	--	2.32	16.73	--	0.77	--	--	7.09	87.05	145.14	100.37	85.18	25.27	9.09
Brantford** System Capacity = 79.55														
Max. Day Demand = 73.27 (1978)	97.00	106.46	117.28	103.32	109.59	87.50	81.18	126.37	155.87	192.00	164.78	166.14	116.73	107.09
Additional Supplies Needed	17.45	26.91	37.73	23.77	30.04	7.95	1.63	46.82	76.32	112.45	85.23	86.59	37.18	27.54
Cambridge System Capacity = 77.23														
Max. Day Demand = 58.48 (1978)	91.32	97.32	100.09	100.73	86.55	79.23	71.87	100.50	135.64	155.05	147.82	124.28	105.59	94.18
Additional Supplies Needed	14.09	20.09	22.86	23.50	9.32	2.00	--	23.27	58.41	77.82	70.59	47.05	28.36	16.95

* Refers to supplies which would be necessary to meet demand after the 1979 source capacity is fully utilized.

** Demand for the City of Brantford is expected to be met wholly through extraction of river water.

*** Refer to Table 3.1 for population projections.

Note: 1 million gallons per day (mgd) = 4546 cubic metres per day (m^3/d)

Future water demands for the major urban centres were based on a range of projected populations (Ref. Tech. Report No. 12) and predicted by assuming that: (1) existing water consumption rates remain the same in the future (base case projection); (2) new conservation methods are implemented with either a moderate or large residential response; or (3) the water rate structure is modified to reflect changing water prices (based on information which predicts response of consumers to anticipated price changes) (Ref. Tech. Report No. 26). By comparing existing supplies with various demand rates and population projections, areas of potential future water shortages can be determined (Tables 6.1 and 6.2).

With the exception of the Cities of Kitchener and Waterloo, shortages of water would probably not be experienced until the year 2001. However, shortages would be felt in all major cities except Brantford by the year 2031 if no new works, conservation measures, or water pricing structures are implemented. Because of the large maximum day demand in the Kitchener-Waterloo area, additional storage, either subsurface or surface, will be required to meet peak demands by the year 2001.

The time at which new supplies will be required is dependent on population growth and the degree of implementation of water conservation practices. Possible sources of water supply investigated by the basin study for the Kitchener-Waterloo area were:

1) additional ground water supplies
2) recharging ground water aquifers with surface water from the Grand river, by induced infiltration or pumping to recharge areas
3) Great Lakes source
4) surface supplies, either from a reservoir or from the river system.

Two possible sources of water supply investigated for the City of Brantford which would individually meet all future municipal water demands were:

1) Great Lakes pipeline from Lake Erie
2) increased use of water from the Grand river.

New development of ground water sources and the Arkell recharge system should meet the water demands of the City of Guelph until 2031. About that time, new sources of supply will be needed if population growth equals the medium or high population projections and no water conservation measures are adopted. Additional supplies would be available from the Guelph reservoir or the Eramosa river.

Of the 23 smaller communities analysed for future water shortages, only Elora and Fergus will experience water shortages by the year 2031 (Table 6.3). Between 2001 and 2031, Elora is expected to experience shortages at the projected low population level, while Fergus is expected to require more supplies if the medium or high population projection is realized. Sources of additional ground water supplies have been investigated (Ref. Tech. Report No. 10).

6.1.4 Industrial Water Requirements

Future water requirements for industries not supplied by a municipal water system were estimated, based on past trends (Ref. Tech. Report No. 26). Projections indicate that the critical areas where existing water supply may become insufficient to meet demand are in the central basin, specifically in the Cities of Kitchener, Waterloo, Cambridge and Guelph.

For these four municipalities, forecasted increases in ground water demand for industrial purposes range from 40 to 111 percent by the year 2001. Concurrently, use of surface water for industrial supply is expected to more than double in Kitchener and Guelph (Table 6.4).

If the low estimate for industrial water demand is realized, adequate water supplies will be available in the central basin to meet industrial needs. The low estimate represents a situation where no new demand for ground water supplies will occur in the Cities of Kitchener, Waterloo and Cambridge. Any further increase in abstraction of ground water for industrial purposes in these cities would affect the availability of water for municipal use thus requiring the implementation of water supply projects before they would otherwise be needed.

SPRAY IRRIGATION OF TOBACCO: Tobacco is an important cash crop in the Whiteman creek area.

6.1.5 Agricultural Water Requirements

Estimates of future water requirements for watering livestock and irrigating crops indicate that the greatest demand will result from increased irrigation (Tables 6.5 and 6.6).

Table 6.3 Summary of Existing Municipal Water Supplies

Community	1976 Serviced Population	1977 Average Daily Consumption (m³/d x 1000)	1977 Maximum Daily Consumption (m³/d x 1000)	1976 Per Capita* Consumption (L/d)	1979 System Capacity (m³/d x 1000)	1979 Source of Water Supply
Arthur	1 628	0.91	1.77	559.10	2.88	6 wells
Ayr	1 331	0.50	N/A	377.28	4.71	2 wells
New Hamburg Baden	4 300	1.86	2.95	431.83	6.28 1.37	2 wells 2 wells
Brantford	69 091	43.96	73.27	636.38	79.54	Grand River
Caledonia	3 774	1.47	2.93	390.92	11.64	5 wells
Cambridge	72 950	38.99	58.48	536.38	77.23	25 wells
Dundalk	1 130	0.51	0.91	454.56	1.96	3 wells
Elmira St. Jacobs	8 095	7.64	12.77	945.48	20.27 0.68	6 wells 2 wells
Elora	2 425	1.12	1.61	463.65	3.04	2 wells
Fergus	5 967	2.80	4.09	468.19	8.02	5 wells
Guelph	71 349	43.18	59.55	604.56	117.32 (W)**	27 wells
Kitchener Waterloo	133 815 51 473	68.80	132.20	445.46	130.96 (S)*** 101.10 39.88 7.42	Arkell Springs 29 wells 12 wells 2 infiltration wells (K-W)
Maryhill	150	0.04	N/A	240.91	0.33	2 wells
Milverton	1 402	0.59	N/A	418.19	1.43	2 wells
Paris	6 993	4.82	7.41	690.92	13.09	2 wells
Plattsville	N/A	N/A	N/A	N/A	1.70	2 wells
Rockwood	N/A	N/A	N/A	254.55	3.93	2 wells
St. George	1 000	0.68	1.05	681.83	8.18	1 well
Cayuga	1 154	0.68	1.09	590.92	1.09	Grand River
Dunnville	5 553	N/A	N/A	N/A	14.55	Lake Erie

* Per capita consumption rates were estimated by dividing the 1976 serviced population into the 1977 average daily consumption rates.

** Winter capacity

*** Summer capacity

N/A Not Available

Table 6.4
Estimated Daily Industrial Water Demand from Private Sources of Supply in Kitchener, Waterloo, Cambridge and Guelph, 2001 and 2031

(cubic metres per day x 1000)

	Existing Water Demand			Estimated Surface Water Demand	Estimated Ground Water Demand	Total Water Demand	Estimated Surface Water Demand	Estimated Ground Water Demand	Total Water Demand
Municipality	Surface Water	Ground Water	Total	2001	2001	2001	2031	2031	2031
Kitchener	2.73	11.21	13.94	5.0 - 5.9	11.2 - 23.6	16.2 - 29.5	7.3 - 9.5	11.2 - 38.2	18.5 - 47.7
Waterloo	0.00	7.68	7.68	- -	7.7 - 16.4	7.7 - 16.4	- -	7.7 - 26.4	7.7 - 26.4
Cambridge	0.00	9.50	9.50	- -	9.5 - 20.0	9.5 - 20.0	- -	9.5 - 32.7	9.5 - 32.7
Guelph	10.04	20.27	30.31	19.5 - 21.4	39.1 - 42.7	58.6 - 64.1	26.8 - 34.5	54.1 - 69.5	80.9 - 104.0
Total	12.77	48.66	61.43	24.5 - 27.3	67.5 - 102.7	92.0 - 130.0	34.1 - 44.0	82.5 - 166.8	116.6 - 210.8

Table 6.5
Livestock Water Demand in the Grand River Basin, 1976, 2001 and 2031

(cubic metres per day x 1000)

Sub-basin Sector	Estimated Livestock Water Demand, 1976	Estimated Livestock Water Demand, 2001	Estimated Livestock Water Demand, 2031
Lower Grand River	5.75	1.66	1.66
Whiteman Creek	2.02	2.06	1.60
Nith River	8.60	12.05	13.99
Paris	0.45	0.45	0.41
Middle Grand River			
Speed River*	1.40	2.63	3.46
Central Grand River	5.63	10.23	13.44
Total	7.03	12.86	16.90
Conestogo River	8.01	9.01	11.67
Upper Grand River	3.14	3.42	3.42
Total	35.00	41.51	49.65

* The Speed river refers to the Speed and Eramosa river watersheds.

Table 6.6
Estimated Irrigation Water Demand and Supply over Main Irrigation Season*

(cubic metres x 1000)

Sub-basin	Existing Demand**	Estimated Maximum Water Demand		Probability of Surface Water Volume Being Equalled or Exceeded		
	1978	2001	2031	.5	.9	.95
Upper Grand River	-	230.55	384.28	16,636.74	8,318.37	5,822.86
Conestogo River	-	267.69	375.96	7,895.63	1,468.22	1,363.67
Middle Grand River						
— Speed River***	44.54	1,913.36	1,945.27	24,741.47	12,663.92	11,959.36
— Central Grand River	6.46	710.61	797.75	30,718.88	10,672.97	9,404.76
Paris		63.50	63.50	2,913.70	1,822.77	1,581.85
Nith River	204.41	2,453.01	2,789.29	34,764.43	21,727.77	18,827.70
Whiteman Creek	1,221.39	1,746.81	1,746.81	10,295.69	7,209.25	6,695.61
Lower Grand River	735.15	964.89	1,010.39	54,542.15	34,091.68	29,755.22
Total	2,211.95	8,350.42	9,113.25	182,508.69	97,974.95	85,411.03
Additional Water Demand Above 1978 Level		6,138.47	6,901.30			

* Calculated for a 92 day period from June to August

** Assuming 5 applications for 24 hours during the main irrigation season

*** Includes Eramosa river watershed

Projections indicate that the number of livestock in the basin will remain relatively stable with the exception of the Nith and middle Grand river basins where an increase is anticipated. The maximum increase in total basin water needs for livestock consumption over the 1980 level is expected to be 18 percent by the year 2001 (Ref. Tech. Report No. 26).

To improve crop yields, irrigation may be feasible on sandy and sandy loam soils. The largest potential irrigation demands are estimated in the basins of the middle Grand and Nith rivers (Table 6.6). In areas of existing high demand, such as the Whiteman creek watershed, increases in irrigation are expected to be less.

Most agricultural irrigation systems in the Grand river basin are supplied by surface water. Based upon a stream flow analysis of several stations, runoff volumes were estimated for the critical drought period from June to August (Table 6.6). Preliminary results indicate that surface water resources should be sufficient to accommodate future irrigation needs. However, detailed subwatershed studies are required to determine more accurately whether or not a local supply problem might exist in the future. Local shortages could occur due to peak demands occurring simultaneously in the watersheds of the Conestogo river below the Conestogo dam and the Speed River above Guelph.

6.2 Flood Damages

6.2.1 Objective

The objective of the basin study relative to flood damage is to minimize property damage, prevent loss of life and encourage a co-ordinated approach to the use of land and management of water. To achieve this objective, the implementation of a mix of structural and non-structural measures is required.

Under the provisions of the Conservation Authorities Act, the Grand River Conservation Authority (GRCA), in co-operation with its member municipalities, is responsible for dealing with problems resulting from flooding in the basin.

6.2.2 Problems

Flooding has occurred periodically throughout the Grand river basin over the course of recorded history (Table 6.7). Flow records at Cambridge (Galt) indicate a definite trend since the early 1920s towards increasing natural flood peaks, which may be due to changing land use practices such as increased acreage of row crops, artificial drainage and expanding urban development. Continued floodplain development in urban areas has contributed to rises in the amount of property damage experienced after major floods. Next to water supply, the public consultation working groups perceived flood damages and water quality as the second most important water management problems in the basin.

FLOODING AT CAMBRIDGE: The May 1974 Flood

Table 6.7 Selected Flood Damage Chronology Within the Grand River Watershed

Date	Community	Resultant Damage
1912 April	Cambridge(Galt)	Cellars were flooded; loss set at minimum of $100,000.
	Guelph	A conservative estimate for flood losses was $76,000.
1913 March	Elora	Damage estimated at $5,000.
	New Hamburg	Damage estimated at $5,000.
	Dunnville	Damage exceeded $5,000.
1918 February	Cambridge(Galt)	Broken gas mains: "thousands of dollars damage to goods stored in the cellars of stores owned by local merchants."
1922 March	Cambridge(Galt)	Thousands of dollars damage.
1928 March	Cambridge(Galt)	Thousands of dollars damage. Some inhabitants of south Water street showed the usual reluctance to leave their homes when first warned by local authorities.
1929 March-April	Cambridge(Galt)	Two bridges were damaged at $15,000. A mile of Water street was flooded. The April flood caused an estimated damage of $250,000. Fifty-seven victims reported a total loss of $120,000.
	Guelph	The loss in manufacturing plants from flooding was reasonably believed to amount to "hundreds of thousands of dollars", without taking account of the damage in the houses.
	Paris	Penman's Manufacturing plants were flooded. The Nith River rampaged. Several houses were badly flooded and one was demolished, half of it going downstream . . . It was the most destructive flood the Nith River has staged in years.
	Brantford	The Grand River left its bed above the city and rushed across the northern flats scattering huge ice floes through the suburbs. There was ice damage at the waterworks, the canal overflowed, fill was washed away, car tracks were flooded and factories threatened.
1932 February	Cambridge(Galt)	Eighteen inches of water inundated Water street.
	New Hamburg Paris	Cellars were flooded resulting in "extensive damage."
	Brantford	The low ground between Birkett's lane and Cockshutt bridge was flooded.
1947 April	New Hamburg	Heavy losses: "Worst flood in thirty-two years."
	Cambridge(Galt)	Nineteen businesses reported damage of $20,300.
	Paris	Spent $2,239 to repair the dykes and $1,858 for cleaning.
	Brantford	Damage exceeded $100,000.
1948 March	Kitchener (Bridgeport)	At least forty dwellings were inundated: damage in the "many thousands of dollars."
	New Hamburg	Thirty-seven homes inundated, water being six inches or more deep on the ground floors. Eleven streets were under water and two approaches to the village were impassable: "largest flood since 1883."

Table 6.7 (Continued)

Date	Community	Resultant Damage			
	Cambridge(Galt)	Damage estimated at $750,000.			
	Brantford	Damage exceeded $100,000.			
	Cambridge(Hespeler)	Damage estimated at $140,526.			
1950 April	New Hamburg	Forty homes were evacuated.			
	Brantford	Damage exceeded $100,000.			
	Waterloo	Heavy losses: "thousands of dollars" damage.			
1954 October Hurricane Hazel	Kitchener (Bridgeport)	Over sixty homes inundated: two hundred people evacuated; total damage $40,000.			
	New Hamburg	At least fifty homes isolated.			
	Cambridge(Galt)	Severe flooding: hundreds of basements flooded.			
1965 February	Cambridge(Galt)	Hundreds of basements flooded.			
1974 May		**Flood Damage Claimed**		**Flood Damage Appraised**	
		No. of Claims Processed	Value Claimed ($)	No. of Claims Approved	Value Appraised ($)
	Brantford				
	Residential	256	285,351	233	206,341
	Non-Residential	47	144,608	38	79,326
	Total	303	429,959	271	285,667
	Cambridge				
	Residential	348	861,917	303	357,186
	Non-Residential	278	3,451,141	245	1,682,712
	Total	626	4,313,058	548	2,039,898
	Kitchener				
	Residential	100	357,266	93	163,330
	Non-Residential	18	151,723	16	71,247
	Total	118	508,989	109	234,577
	Paris				
	Residential	59	59,587	52	37,359
	Non-Residential	36	190,996	33	69,811
	Total	95	250,583	85	107,170
	All Other				
	Residential	39	84,609	29	61,940
	Non-Residential	19	131,236	15	50,841
	Total	58	215,845	44	112,781
1975 April	Paris	Cost of emergency flood prevention $50,000; estimated damage on Elm street was $900.			
1976 June	Conestogo	Damage was $15,000 to $18,000.			
1979 March	Paris	Flooding caused by ice jam: "thousands of dollars" damage.			

Note: Damages in dollars are referenced to the time losses were reported.
Source: Ref. 6.

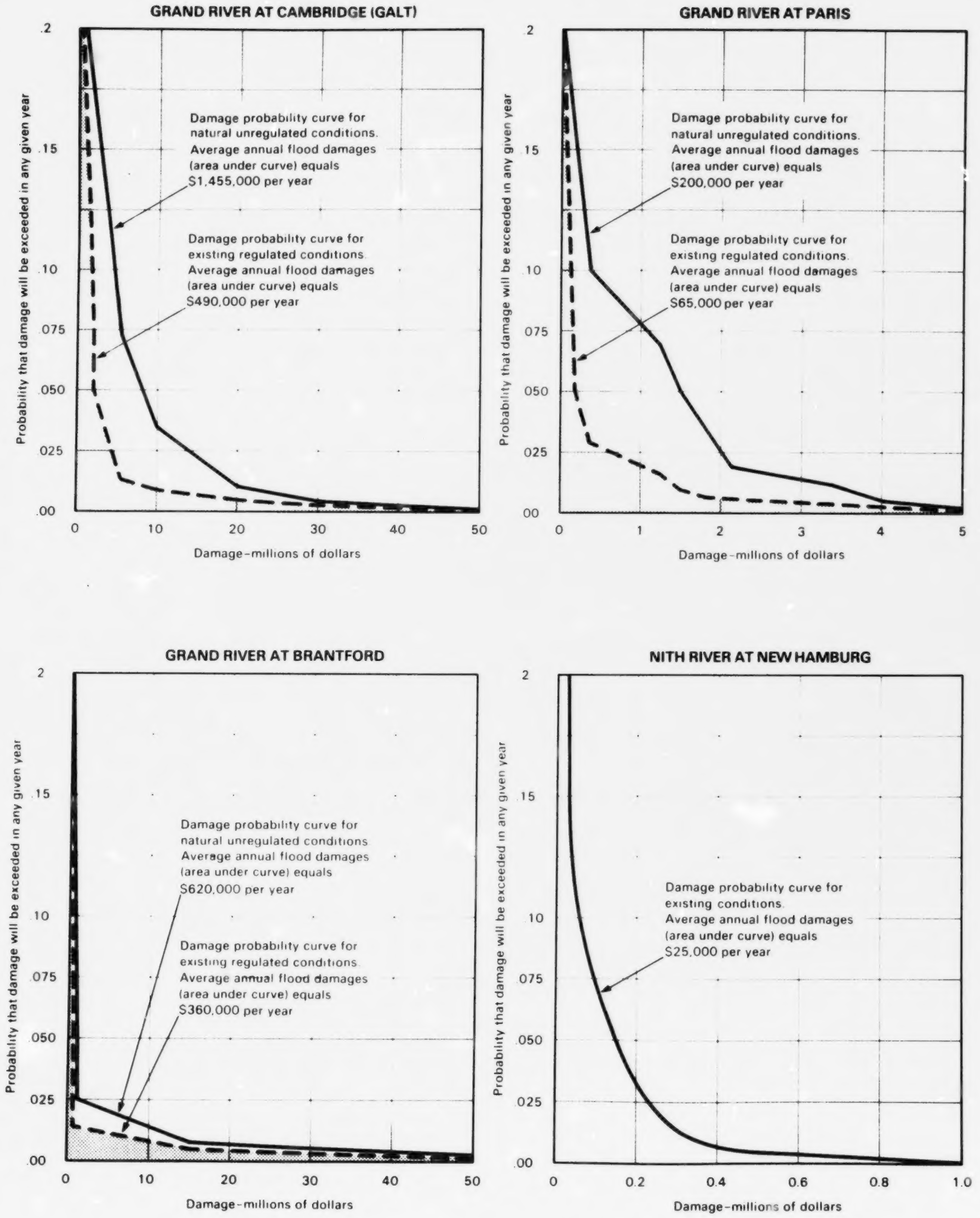


Figure 6.1. Flood damage versus probability of exceedance (1979 damages).

The main measures that are used in the basin to reduce flood damages include dams, dyking and channelization, flood warning systems and regulation of floodplain development.

Three major dams, the Shand (1942), Conestogo (1958), and Guelph (1976) are operated by the Grand River Conservation Authority to reduce flood peaks on the Grand, Conestogo and Speed rivers. Under 1980 operating policies, it is estimated that average annual flood damages are reduced by 63 percent as compared to those which would occur under natural conditions.

Since the early 1950s, various dyking and channelization projects have been carried out jointly by the Grand River Conservation Authority and the benefiting municipalities, in Paris, New Hamburg, Guelph, Cambridge (Hespeler) and Caledonia. A major dyking and channelization project was completed in Kitchener (Bridgeport) in 1980, and similar projects are underway in Cambridge (Galt) and Brantford.

During a flood crisis, a flood warning system, co-ordinated by the Grand River Conservation Authority, alerts basin residents of imminent flooding. Residents are encouraged to reduce personal property damage by moving personal items to higher locations and/or by evacuating their premises.

The regulation of floodplain development is the responsibility of both basin municipalities and the Grand River Conservation Authority. Through co-ordinated efforts, an active program restricting urban floodplain development exists. The present policy of the GRCA recognizes the selective application of a two-zone floodway-fringe concept in urban areas. The floodway is the area of floodplain required to pass deep, fast-flowing flood waters where most development is prohibited. The fringe is the area along the outer limits of the floodplain where the depth of flooding is shallow and the risk of flood damage is low. Some development is allowed in the fringe area, subject to flood proofing stipulations.

Despite the application of measures which have reduced flood damages, average annual damages in the basin are estimated at $980,000. The probability of the occurrence of spring flood flows, with and without the existing reservoirs, and the associated damages at the four urban centres sustaining the highest average annual damage are shown (Fig. 6.1). In addition, risk of flooding as a result of tropical storms and the formation of ice jams also exists. Ice jams frequently cause flooding in Grand Valley, West Montrose, Kitchener, Paris, Brantford, Dunnville, Eden Mills, Rockwood and New Hamburg. They occur during an early spring breakup at locations where moving ice flows are slowed due to a constriction or solid ice front.

ICE JAM FLOODING: Flooding at West Montrose, (February, 1981) caused by an ice jam downstream of the hamlet.

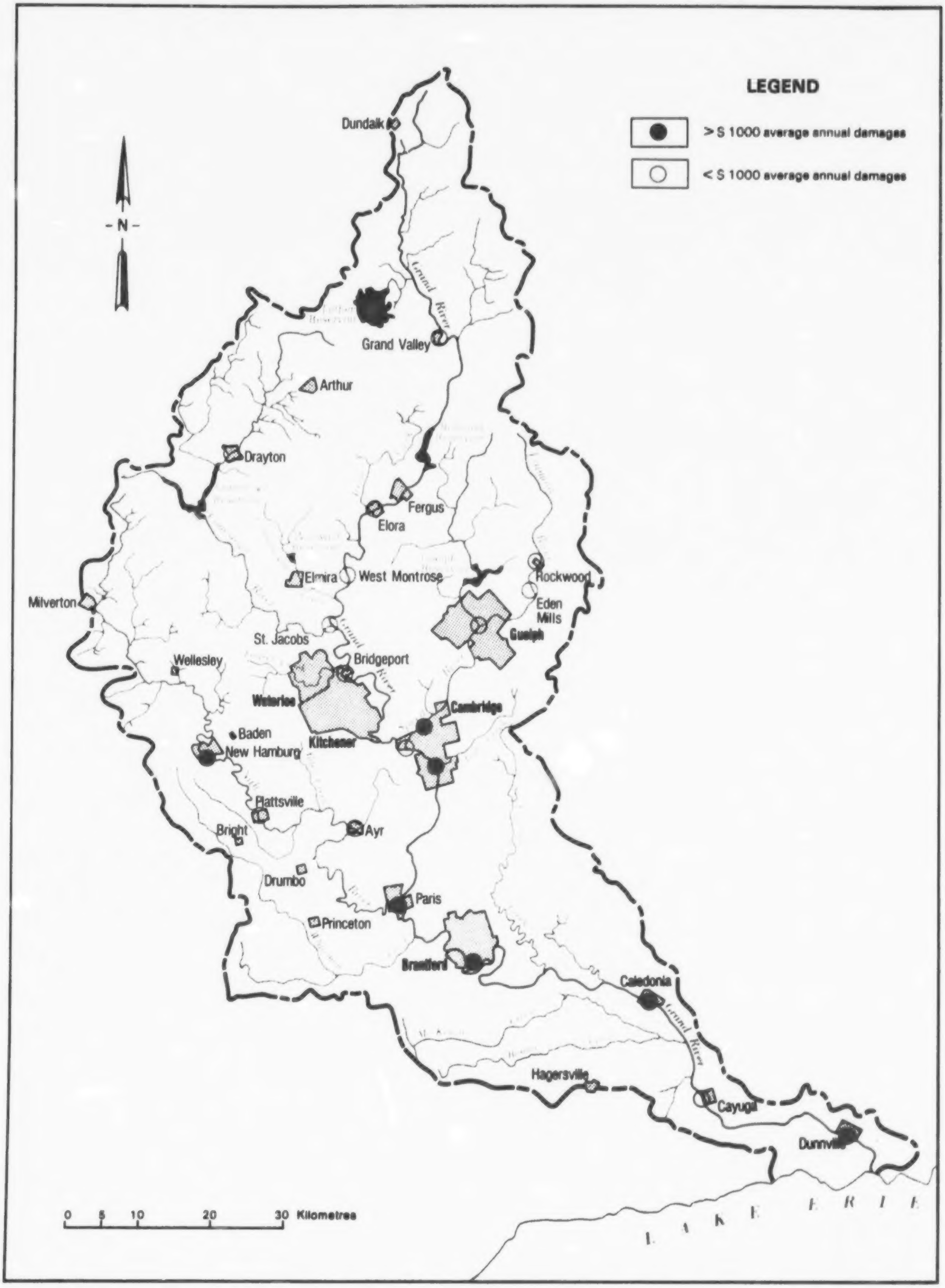

LEGEND
● > $ 1000 average annual damages
○ < $ 1000 average annual damages
N
Dundalk
Grand River
Grand Valley
Arthur
Drayton
Fergus
Elora
Elmira
West Montrose
Rockwood
Eden Mills
Guelph
Milverton
St. Jacobs
Bridgeport
Wellesley
Waterloo
Cambridge
Baden
New Hamburg
Kitchener
Plattsville
Bright
Ayr
Drumbo
Paris
Princeton
Brantford
Caledonia
Hagersville
Cayuga
Dunnville
0 5 10 20 30 Kilometres
LAKE ERIE

Figure 6.2. Communities prone to frequent flooding.

Although increases in flood peaks over the past sixty-five years have been partially offset by the flood control capabilities of the existing reservoir system, further increases are expected if changes in land use patterns continue.

A total of twenty basin communities are prone to varying degrees of flood damage (Fig. 6.2). Six communities, (Cambridge, Paris, Brantford, New Hamburg, Caledonia and Dunnville) are subjected to average annual damages greater than $1,000/year. To minimize flood damage in the basin, a combination of additional structural and non-structural methods were investigated by the basin study:

1) new reservoirs
2) dyking and channelization
3) floodplain acquisition
4) flood proofing
5) flood warning
6) floodplain zoning
7) flood insurance
8) reforestation.

6.3 Water Quality

6.3.1 Objective For Surface Water Quality

The goal of the Province of Ontario for surface water quality management as stated in "Water Management — Goals, Policies, Objectives and Implementation Procedures of the Ministry of the Environment" (Ref. 7) is to ensure that surface waters are of a quality which is satisfactory for aquatic life and recreation (public health). Waters meeting these requirements will, in most cases, be suitable for other beneficial uses such as drinking water and agriculture.

To achieve this goal, numerical and descriptive objectives for a wide variety of physical, chemical and microbiological parameters have been set and are called the provincial water quality objectives. The intent of the water quality component of the basin study is to achieve the policies of maintaining high water quality where it exists and upgrading water quality where conditions are not in compliance with the objectives.

6.3.2 Problems with Surface Water Quality

In the following sections, the key parameters of water pollution — oxygen-consuming materials, nutrients and aquatic plants, bacteria, suspended sediments, trace contaminants and toxic substances — are briefly discussed in terms of their sources, effects on water quality and uses, implications of future development, and general management control strategies.

Oxygen-Consuming Materials

The decomposition of organic material, usually compounds of carbon and nitrogen, is achieved by bacterial action. When converting organic substances, bacteria draw oxygen from the water and change various compounds to stable forms such as carbonates and nitrates. The amount of oxygen required and the impact of this process of assimilation on the dissolved oxygen regime of the river are dependant upon several factors including the amount of oxygen-demanding material introduced; dissolved oxygen concentrations in the stream and the stream's reaeration ability; water temperature; and the photosynthesis-respiration activity of aquatic plants and algae.

Typically, the impact on dissolved oxygen is most severe within a few kilometres downstream from the point of discharge with gradual improvement as the oxygen-demanding substances are oxidized and normal conditions are once again established. This pattern can be altered substantially by the presence of several sources in the same vicinity and/or the presence of nuisance levels of aquatic plants or algae.

The Ministry of the Environment suggests that for the protection of warm-water biota, which occupy most reaches of the Grand river basin, dissolved oxygen levels should not fall below 47 percent saturation (i.e. 4 milligrams per litre (mg/L) at 20°C (68°F)) (Ref. 7).

Throughout most reaches of the Grand river and its tributary streams, oxygen-consuming waste inputs do not alter the dissolved oxygen regime severely and the objective is generally met. This is the result of a combination of adequate natural assimilation capabilities, sustained streamflow, and adequate sewage treatment or discharge procedures at those sewage treatment facilities serving the smaller communities. Some agricultural sources of organic material, such as feedlot runoff and silage liquors, have the potential to affect the dissolved oxygen regime and could have a significant impact on local aquatic life.

The most serious environmental impacts resulting from the discharge of oxygen-consuming substances are found in the central Grand river downstream from the Kitchener sewage treatment plant in the Regional Municipality of Waterloo, and in the lower Speed river downstream from the Guelph sewage treatment plant. A detailed record of variations in dissolved oxygen levels in these areas is presented in Technical Reports 11 and 11a.

FISHING: At Caledonia on the Grand river

In the central Grand river, the Waterloo, Kitchener, Preston and Galt sewage treatment plants discharge approximately 225,000 m^3/d (49 mgd) of treated sewage or about 60 percent of the total input from all sewage treatment plants in the basin. The demands exerted upon the river to satisfy the oxygen requirements of wastes from these plants, in combination with nuisance aquatic plant growths in the same area, reduce night-time dissolved oxygen levels on many occasions to less than 1 mg/L downstream from the Kitchener sewage treatment plant and keep levels well below the 4 mg/L objective downstream from Kitchener, through Cambridge and past Glen Morris. These depressed conditions do not exist all the time; rather, they are usually measured for several hours during the nights in the summer-fall period.

Dissolved oxygen levels in the lower Speed river are influenced by oxygen-consuming wastes discharged from the Guelph and to a much smaller extent Hespeler sewage treatment plants and by dense aquatic plant growths downstream from Guelph. Prior to the recent installation of nitrification facilities at Guelph, dissolved oxygen levels often fell to zero for extended periods at night during the summer and fall. With the new facilities at Guelph which will substantially reduce the carbonaceous and nitrogenous oxygen-demanding wastes, it is expected that minimum dissolved oxygen levels will seldom fall below 2 mg/L and the number of hours within a day when the dissolved oxygen objective is not met will be reduced.

Oxygen-consuming wastes discharged from the Brantford sewage treatment plant do not significantly affect dissolved oxygen levels in the lower Grand river. This river reach has a substantial streamflow, a high assimilative capacity, and is not affected by nuisance levels of aquatic plant growth.

Although not directly affected by organic material inputs from sewage treatment plants, the dissolved oxygen levels of the three major reservoirs – Belwood, Conestogo and Guelph – are influenced by the oxygen demands of decaying algae and river detritus. Each year, in the early summer, thermal barriers are established at about mid-depth in each reservoir. These barriers prevent mixing of the surface and bottom waters. Oxygen resources in the bottom waters are depleted gradually by decaying organic material in the water column and on the reservoir bottom, making this zone of the reservoir unsuitable for fish. Depleted oxygen resources also result in the conversion of nitrogen to its ammonia form and the release of metals from the sediments to the water column. Water discharged from these reservoirs is commonly drawn from below the thermal barrier. While the depleted oxygen in the released water is replenished quickly in the river below the dam, the residual impact of the pollutants formed, such as ammonia, can affect downstream uses.

Investigation and modelling carried out to evaluate the impact of stormwater drainage from large basin municipalities show that oxygen-demanding wastes in stormwater carried into the Grand and Speed rivers do not have a detrimental impact on dissolved oxygen levels. A number of factors contribute to this, including the increased diluting effect of higher streamflows, higher reaeration capacity due to increased turbulence and the availability of dissolved oxygen in rainwater.

Oxygen-demanding waste discharges from within the river basin do not significantly affect the dissolved oxygen regime of Connor Bay in Lake Erie at the mouth of the Grand river.

Suggested Remedial Actions

Oxygen depression in the middle Grand river below Waterloo and Kitchener can be reduced to some degree by installing facilities to reduce nitrogenous oxygen-demanding wastes or by augmenting streamflow during the critical summer period. The provincial objective of 4 mg/L cannot be achieved continuously without a reduction of aquatic plant growth in this area of the basin.

The recently installed nitrification facilities at Guelph will greatly increase dissolved oxygen levels in the lower Speed river but the objective cannot be met in summer without a reduction in the level of aquatic plants and additional streamflow augmentation.

While the Brantford sewage treatment plant and the sewage treatment facilities serving the smaller communities in the basin do not seriously impair dissolved oxygen, future expansions may require higher than secondary level of treatment or streamflow augmentation to prevent water quality degradation.

Formation of a thermal barrier and the resultant dissolved oxygen depression in the deep water areas of the large reservoirs is a normal phenomenon influenced to some extent by upstream land use activities that cause nutrient enrichment and faster algae growth. Aside from increasing mixing and aeration within the reservoir, there do not appear to be practical solutions to this problem.

Nutrients and Aquatic Plants

The availability of nutrients affects the growth of aquatic plants and algae, both attached and free-floating. Although the term nutrient encompasses many elements, nitrogen and phosphorus are recognized as major nutrients affecting growth. Given an adequate supply of these nutrients in addition to energy from the sun and appropriate river bottom, temperature, and current conditions aquatic plants and algae will grow to fill all of the space available. Such nuisance growths occur at several locations in the basin and contribute to the serious dissolved oxygen problems in the Grand river below Kitchener and in the Speed river below Guelph. The abundance and distribution of aquatic plants and algae as measured during surveys conducted in 1979 are illustrated in Figure 6.3. A complete review of aquatic plants is contained in Technical Report No. 42.

In addition to the growth of aquatic plants, nutrient enrichment stimulates the growth of free-floating algae in the reservoirs and deep, quiescent reaches of the river. These algal growths and periodic blooms contribute to general aesthetic impairment and diurnal dissolved oxygen fluctuations in the surface waters of the reservoirs. When the algae die and sink to the bottom of a reservoir they decay and exert an oxygen demand on the deep water zone.

In urban areas the principal sources of nitrogen and phosphorus compounds are municipal sewage treatment plants, storm water runoff and occasionally, during severe storm events, by-passed municipal sewage (Ref. Tech. Report No. 28). All major municipal sewage treatment facilities in the Grand river basin provide phosphorus removal to the level of 1 mg/L to conform with International Joint Commission guidelines for the protection of the lower Great Lakes. Specific treatment to remove nitrogen is not employed at municipal facilities along the Grand river. The Guelph sewage treatment plant, however, provides treatment to convert ammonia and organic nitrogen to the more stable inorganic form (i.e. nitrate) (Ref. 8). This treatment was prescribed to reduce the oxygen demand and toxic effects of the discharge on the Speed river downstream from the plant.

In rural areas, nitrogen and phosphorus can enter watercourses from a wide variety of sources including precipitation, land runoff, municipal drains, drainage from feedlots or barnyards, and malfunctioning private sewage treatment systems. As phosphorus compounds associate readily with soil particles, soil erosion during spring thaws or storm events is the most significant mechanism for the transport of phosphorus to watercourses. Nitrogen compounds are largely water soluble and can gain access to streams by overland transport, infiltration through the soil or interception by tile drains (Ref. Tech. Report No. 27).

EXCESS GROWTH OF AQUATIC PLANTS: This growth results in low dissolved oxygen levels in the Speed river below Guelph and in the middle Grand river

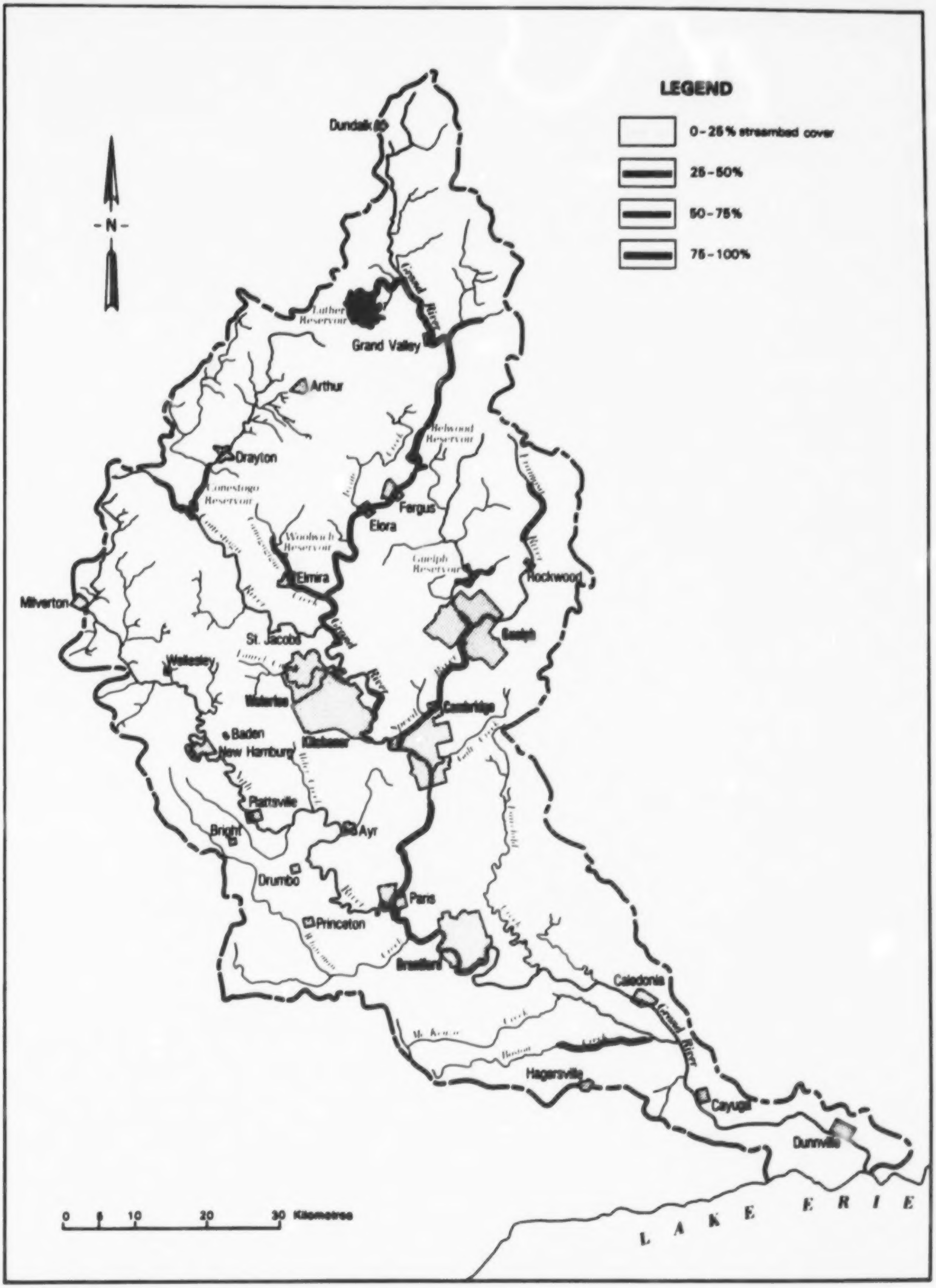

LEGEND
0 - 25 % streambed cover
25 - 50%
50 - 75%
75 - 100%
N
Dundalk
Luther Reservoir
Grand River
Grand Valley
Arthur
Belwood Reservoir
Irvine Creek
Drayton
Conestogo Reservoir
Fergus
Elora
Conestogo River
Canagagigue Creek
Woolwich Reservoir
Guelph Reservoir
Eramosa River
Elmira
Rockwood
Milverton
Guelph
St. Jacobs
Laurel Creek
Wellesley
Speed River
Waterloo
Cambridge
Baden
Kitchener
New Hamburg
Nith River
Alder Creek
Mill Creek
Plattsville
Bright
Ayr
Drumbo
Fairchild Creek
Paris
Princeton
Whiteman's Creek
Brantford
Caledonia
McKenzie Creek
Boston Creek
Hagersville
Cayuga
Dunnville
0 5 10 20 30 Kilometres
LAKE ERIE

Figure 6.3. Aquatic macrophyte distribution and abundance – 1979.

In evaluating the effects of nutrients on water quality in the Grand river basin, two important aspects to consider are the magnitude of the various sources of nitrogen and phosphorus and the seasonal distribution of inputs to the watercourse. The annual and seasonal (i.e. winter-spring, summer-fall) distribution of loadings of total and filtered reactive phosphorus as well as total Kjeldahl nitrogen (organic nitrogen + ammonia) and nitrite and nitrate nitrogen in the basin are shown in Table 6.8.

In the upper basin north of the City of Waterloo, the bulk of nutrient input throughout the year can be attributed to rural drainage. Contributions from the relatively small sewage treatment plants in the upper basin, although perhaps locally important, are rather insignificant compared to contributions from rural drainage.

In the Speed river basin, sewage treatment plants and rural drainage annually contribute about the same amount of total phosphorus. Urban drainage contributes a much smaller amount. Filtered reactive phosphorus which is readily available to stimulate growth of aquatic plants and algae enters largely from the sewage treatment plants. On a seasonal basis, nutrient inputs from rural sources dominate during the winter-spring period reflecting the impact of spring thaw runoff. During the summer-fall period of reduced runoff, loadings from the sewage treatment plants contribute a larger percentage of the total nutrient input.

The information for the upper and middle basin incorporates all sources of nutrients to a point just north of Paris and includes the contribution of all the major sewage treatment plants with the exception of the one which serves Brantford. Rural drainage sources contribute the largest proportion of most nutrient forms and these sources dominate during the winter-spring period. However, during the summer-fall period the relative significance of sewage treatment plants increases substantially.

For the total basin, rural non-point sources contribute the largest proportion of nutrient input, particularly during snow melt and storm events of the late winter-early spring period. These winter-early spring discharges have a minimal effect on the flowing reaches of the river because they do not occur during the primary aquatic plant growing season. However, they contribute to overall enrichment of the major reservoirs and Lake Erie. Nutrient inputs from sewage treatment plants are most significant during the summer-fall period and their impacts are primarily measured in aquatic plant and algae

Table 6.8
Contributing Sources and Seasonal Distribution of Phosphorus and Nitrogen Loadings

River Section	Nutrient Loadings (tonnes)			Contributing Sources and Seasonal Distribution of Loadings								
		Winter	Summer	ANNUAL			WINTER-SPRING			SUMMER-FALL		
	Annual	Spring	Fall	STP*	UD**	RD***	STP*	UD**	RD***	STP*	UD**	RD***
Total Phosphorus												
Upper Basin (To Bridgeport)	80	60	20	4	1	95	2	1	97	12	1	87
Speed River Basin	40	20	10	47	11	42	30	15	55	72	6	22
Upper & Middle Basin (To Paris)	290	200	90	30	8	62	18	9	73	56	5	39
Total Grand River Basin	350	190	160	22	5	73	12	6	82	45	4	51
Filtered Reactive Phosphorus												
Upper Basin (To Bridgeport)	25	20	5	6	0	94	3	0	97	16	0	84
Speed River Basin	7	3	4	76	3	21	61	5	34	90	1	9
Upper & Middle Basin (To Paris)	80	50	30	44	2	54	28	2	70	70	1	29
Total Grand River Basin	125	80	45	47	2	51	23	2	75	64	1	35
Total Kjeldahl Nitrogen												
Upper Basin (To Bridgeport)	600	470	130	5	0	95	3	0	97	13	0	87
Speed River Basin	220	170	50	8	8	84	4	3	88	21	7	72
Upper & Middle Basin (To Paris)	1900	1100	800	50	6	44	33	8	59	75	3	22
Total Grand River Basin	2800	1800	1000	41	5	54	26	6	68	68	2	30
Filtered Nitrite & Nitrate Nitrogen												
Upper Basin (To Bridgeport)	1050	850	200	1	0	99	1	0	99	4	0	96
Speed River Basin	350	250	100	25	1	74	14	1	85	49	2	49
Upper & Middle Basin (To Paris)	3450	2600	850	11	1	88	6	1	93	26	1	83
Total Grand River Basin	6000	4600	1400	8	1	91	4	1	95	20	1	79

*STP - sewage treatment plant
**UD - urban non-point or diffuse sources
***RD - rural non-point or diffuse sources

growth in the river and its tributaries. During the summer, nutrient inputs from sewage treatment plants dominate in the Speed river with rural sources contributing a minor amount of nutrients. However, in the main Grand river below Waterloo, rural sources provide a significant summer nutrient input which, along with the sewage treatment plant input, contributes to aquatic plant growth in the central Grand river.

The Grand river is also a major source of nutrients in the Ontario coastal zone of the eastern basin of Lake Erie. The average annual total phosphorus and total nitrogen loadings are in the order of 500 and 9,000 tonnes respectively. The Grand river discharges to Connor Bay and locally, in that bay, the nutrient inputs stimulate algae growth in an area extending about 4 km (2.5 miles) from the river's mouth. Studies of nutrient enrichment from the Grand river on a larger, eastern Lake Erie basin scale, indicate that the plume from the river extends in an easterly direction for a maximum distance of about 14 km (8.7 miles). In this plume, algae growths are slightly higher than normal background levels measured in Lake Erie to the west of the Grand river (Ref. 8). Phosphorus control measures taken to reduce nuisance aquatic plant growth and resultant dissolved oxygen problems in the river will also benefit the lake.

Suggested Remedial Measures

In order to reduce excessive aquatic plant growth, the Ministry of the Environment guideline for total allowable phosphorus in rivers and streams is 0.03 mg/L. Based on water quality monitoring records from stations throughout the Grand river basin, this guideline is exceeded virtually everywhere in the main stem and major tributaries. Nutrient enrichment results in localized nuisance conditions documented at several locations in the basin.

The combined effects of oxygen-demanding waste water discharges from sewage treatment plants and excessive aquatic plant growth cause serious dissolved oxygen problems in the main Grand river between Kitchener and a point north of Paris and in the Speed river from Guelph to its confluence with the Grand river. Water quality models indicate that controlling oxygen-consuming inputs at appropriate sewage treatment plants will improve dissolved oxygen conditions in these river reaches but will not achieve the 4 mg/L dissolved oxygen objective continuously. Modelling also shows that further phosphorus control at the Guelph sewage treatment plant would reduce biomass growth and improve dissolved oxygen conditions in the lower Speed river. However, similar benefits would not be achieved in the Grand river below Kitchener through further phosphorus control exclusively at the sewage treatment plants. Very large reductions from both sewage treatment plant and upstream, rural land drainage sources would be required to eliminate nuisance aquatic plant production below Kitchener. Reductions of excessive plant growth at several locations in the upper Grand river basin and algal growth in the major reservoirs could only be achieved through rural non-point source nutrient control.

Bacteria

The enumeration of coliform bacteria traditionally has been used to evaluate water quality with respect to public health. While coliform organisms are not normally regarded as causing health problems, their presence in a waterbody indicates the possible presence of pathogenic bacteria which can cause health disorders such as eye, ear, nose, throat or skin infections or serious diseases such as typhoid fever.

Bacterial contaminants in urban areas can originate as the result of ineffective chlorination at sewage treatment plants, illegal discharges of sanitary wastes to storm sewers or directly to watercourses, or from urban stormwater runoff which is contaminated by fecal matter from wild animals or pets.

In agricultural areas, land runoff carries fecal matter from such sources as manure piles, barnyards, feedlots and pasture lands. In addition, livestock and wildlife defecating directly in streams while watering, and seepage from malfunctioning septic tank systems can contribute to bacterial contamination of rural watercourses.

The Ministry of the Environment recommends that in areas used for body contact recreation, a potential health hazard exists if the total coliform and fecal coliform densities of a specified series of samples exceed 1,000 and 100 per 100 millilitres (mL), respectively. A review of recent results from the Ministry of the Environment's water quality monitoring program indicates that bacterial densities are generally below these levels in the upper reaches of the Grand river downstream to the confluence with Canagagigue creek and in the lower Grand river downstream from Caledonia. Elevated levels were measured throughout the highly populated areas of the central basin, in the Speed river below Guelph, Canagagigue creek below Elmira, the lower reaches of the Conestogo river and thoughout the Nith river basin (Ref. 9).

The Grand River Conservation Authority, in co-operation with local Ministry of Health offices, conducts weekly bacteriological sampling of all of the public swimming areas under their jurisdiction. Bacteriological conditions in these areas are good. Over the past six years there have only been two instances when it was necessary to close the beach for a few days.

Lake Erie, in the vicinity of the Grand river mouth, is not substantially affected by bacterial contaminants generated within the basin.

SWIMMING: At Rockwood on the Speed river

A detailed evaluation of bacterial contaminants in the Grand river is presented in a recent report prepared for the IJC-PLUARG studies (Ref. 10). Some of the general findings are:

- the impact of adjacent land uses on bacterial water quality is most pronounced in small sub-watersheds (urban and rural) due to low streamflows which do not provide adequate dilution of bacterial contaminants.
- bacterial pollution is localized and site specific. Generally, micro-organisms are not transported downstream great distances from pollution sources.
- seasonal variations in populations of indicator organisms suggest that the maximum contribution of bacterial pollutants occur during the summer and fall periods. Bacterial inputs during the winter and spring months are generally low.

Suggested Remedial Measures

In order to control bacterial contamination in urban and rural areas, remedial measures must be applied at the sources of pollution. In rural areas, runoff from barnyards, feedlots, manure piles, etc., should be directed away from watercourses. In urban areas, regular street sweeping and storm sewer maintenance programs should be practised. Sewage treatment facilities should be operated to maximize the effectiveness of chlorination and, wherever possible, disinfection should be provided to any sewage bypassed during severe storms or during plant breakdowns.

Suspended Sediments

Suspended sediments in a river render the water aesthetically unattractive because of the resultant muddy or milky appearance. High levels of suspended sediments may interfere with uses such as swimming or water supply and can exert stresses on fish (Ref. Tech. Report No. 13). Subsequent deposition of organic particulate material can exert a demand on the oxygen resources of the watercourse.

In considering various water pollution control measures, it is also important to note that phosphorus, some heavy metals, pesticides and other organic substances readily associate with and are carried by particulate matter.

Sources of suspended sediment are rural areas, urban areas and sewage treatment plants. Rural areas, contributing over 90% of the total basin loading, are the major source of suspended sediments. In rural areas, a combination of physical characteristics such as soil type and slope, and man's activities such as cropping and tillage practices has contributed to increased suspended sediment loadings throughout the basin (Ref. Tech. Report No. 27).

RURAL SOIL EROSION: Over 90 percent of the total river suspended sediment loadings comes from rural sources

The major source of suspended sediment from urban areas is stormwater runoff from construction sites. Table 6.9 shows the sediment-contributing sources and seasonal distribution of suspended loading at four locations in the Grand river basin. Approximately 80 per cent of the annual suspended sediment input occurs during late winter-early spring snow thaws and storms.

URBAN SOIL EROSION: The majority of urban erosion results from construction activities

In most areas, inputs from rural sources dominate, but in highly urbanized tributary areas such as those found in the central basin, urban non-point sources can be significant.

An evaluation of Connor Bay in Lake Erie shows that the discharge of suspended sediments from the Grand river has little environmental impact. The implications of trace pollutants carried to the lake with the suspended sediments have not been assessed.

Suggested Remedial Measures

Control of particulate loading in the Grand river basin is required to minimize physical effects such as turbidity and stream-bed sedimentation. As well, such controls would reduce the input of phosphorus and trace contaminants which associate with solids from point sources as well as urban and rural land drainage. Control programs can range from relatively inexpensive measures which are easy to implement to costly procedures which are difficult to implement. Efforts should be directed to implementing all practical methods of reducing suspended sediment inputs from urban and rural areas. However, because the river passes through clay plains where fine sediments can be entrained, sections of the river such as the lower Grand will always be turbid.

Trace Contaminants

Trace contaminants are substances such as heavy metals, pesticides and industrial organic compounds which may occur in water in the parts per billion range or less. If present in sufficient concentrations, these contaminants can affect the health and survival of fish and other aquatic organisms, particularly in areas of a watercourse where dissolved oxygen is depleted. Substances such as mercury, in its organic or methylmercury form, and some organic compounds such as mirex and polychlorinated biphenyls (PCBs) can bioaccumulate in fish, sometimes to the point where consumption by humans should be

Table 6.9
Contributing Sources and Seasonal Distribution of Suspended Sediment Loadings

River Section	Suspended Sediment Loading tonnes x 1000			Contributing Sources and Seasonal Distribution of Loading								
				ANNUAL			WINTER SPRING			SUMMER FALL		
	Annual	Winter Spring	Summer Fall	STP*	UD**	RD***	STP*	UD**	RD***	STP*	UD**	RD***
Upper Basin (To Bridgeport)	36	29	7	0	0.1	99.9	0	0.1	99.9	0	0.2	99.8
Speed River Basin	5	4	1	4	42	54	2	43	55	12	38	50
Upper & Middle Basin (To Paris)	156	125	31	1	8	91	0	8	92	2	8	90
Total Grand River Basin	275	220	55	1	6	93	0	6	94	2	6	92

*STP sewage treatment plant
**UD urban non-point diffuse sources
***RD rural non-point diffuse sources

restricted or stopped. Elevated levels of trace contaminants can also affect the suitability of water for municipal water supply or agricultural uses such as livestock watering and irrigation.

Metals are elements of the earth's crust and can be found naturally in low concentrations virtually everywhere. Also, they are contained in sewage treatment plant discharges, industrial wastes, urban stormwater drainage and rural land drainage. Domestic and industrial effluents from municipal sewage treatment plants and urban land drainage, including atmospheric fallout of pollutants such as lead from automobile exhaust, appear to be the most significant sources of metals in the Grand river basin.

Pesticides and many industrial organic compounds do not occur naturally and their presence is attributable to man's activities. Pesticides, including herbicides, fungicides, and insecticides are used for insect and weed control in both rural and urban areas and are found in runoff from both types of areas and in sewage treatment plant discharges. Industrial organic compounds are used virtually everywhere. Electrical equipment, paints, solvents, caulking compounds, printing ink, plastics, cosmetics and pharmaceuticals are only a few of the products in which industrial organics have been used. Because of their widespread use, these compounds are present in sewage treatment plant discharges and land drainage, most notably from urban areas.

The dioxin compound 2,3,7,8-TCDD is an extremely toxic organic chemical found as an unwanted by-product in the herbicide 2,4,5-T. During the 1960s, large quantities of 2,4,5-T were processed at Uniroyal Ltd. in Elmira. Extensive testing of surface and ground water and fish has been carried out at Elmira. No trace of this dioxin has been found in samples analyzed to date. Testing is continuing.

Through routine monitoring programs and the PLUARG studies, samples for metals and pesticides analysis have been collected at several locations in the Grand river basin. Heavy metals data for a monitoring station at Glen Morris were compared to the provincial water quality objectives for the protection of aquatic life (Ref. 7). Chromium, nickel and arsenic met the objectives but lead, zinc, copper and cadmium slightly exceeded them. No studies have been undertaken to determine if those metals exceeding the objectives are significantly affecting the aquatic communities. An evaluation of the metals data with respect to the Ministry of the Environment's criteria for drinking water, livestock watering and irrigation shows that all the metals are well within the acceptable limits for these uses.

DETECTING CONTAMINANTS: This requires expensive and elaborate equipment as shown here at MOE lab

Pesticides data collected at the mouth of the Grand river for the PLUARG studies show that DDT, dieldrin, chlordane, heptachlor epoxide, endosulphan, endrin, lindane and atrazine are present but well within the Ministry of the Environment's objectives for the protection of aquatic biota and livestock watering (Ref. 7). Concentrations also meet Health and Welfare Canada's guidelines for drinking water. PCB levels slightly exceed the objective for the protection of aquatic biota but are well within the Ministry of the Environment's proposed guideline for drinking water. There is no PCB guideline for agricultural uses of water.

To measure the levels of trace contaminants in sport fish, specimens were collected from the lower Grand river from Caledonia to Lake Erie; the Grand river near Kitchener and the Speed river in Cambridge. Mercury concentrations in most fish are low, however, concentrations in some of the larger fish of predatory species such as walleye, northern pike, smallmouth bass and coho salmon are elevated to the point where consumption should be restricted to a few meals per week. Only the very large walleye, over 65 centimeters (2 ft) in length, from the lower Grand river are not suitable for any consumption. PCBs were present at low concentrations in all fish tested but impose no restriction on consumption. Mirex was not detected in any of the fish tested. Fish from Canagagigue creek, upstream and downstream from Elmira have been tested for the dioxin — 2,3,7,8-TCDD. This substance was not detected in any fish from the creek. Detailed information on contaminants in sport fish from the Grand river as well as consumption advice is contained in the Ministry of the Environment publication "Guide to Eating Ontario Sport Fish — Southern Ontario, 1981" (Ref. 11).

In recent years, scientists have developed methods of testing for very low concentrations of literally thousands of industrial organic compounds. Due to the high costs of analysis and limited laboratory capacities, data on the presence of these substances in the waters of the Grand river are sparce. Samples collected for the basin study from Canagagigue creek, the Grand river from Canagagigue creek to Caledonia and the Speed river, show the presence of a wide variety of organic compounds at very low concentrations. While there have been few objectives or guidelines established for these compounds, a review of available literature indicates that concentrations of substances measured to date from the Grand river should pose no threat to aquatic life or use of the river for water supply.

Suggested Remedial Measures

While some trace contaminants are soluble in water, many associate with particulate matter. Advanced sewage treatment for nitrification and effluent filtration at major sewage treatment plants should reduce suspended solids loadings and thus particulate-associated substances.

Methods to minimize suspended solids inputs from rural and urban non-point sources would also result in a reduction of trace contaminant loadings.

In order to identify the type and location of future remedial measures which would be carried out, further industrial organic compound sampling should be carried out in the Grand river and its major tributaries as well as in sewage treatment plants and urban drainage systems and major municipal ground water aquifers, to identify sources and concentrations of key trace contaminants. Particular emphasis should be placed on sampling municipal water supply withdrawal locations. Appendix E outlines a proposed organic contaminant monitoring program.

Toxic Substances

Chlorine and un-ionized free ammonia are two toxic substances which can stress or kill fish and other aquatic life forms at relatively low concentrations.

Chlorine is used as a disinfectant at all conventional sewage treatment plants in the basin to eliminate bacteria and other disease causing micro-organisms before the treated wastewater is discharged to the river. In order to ensure disinfection, common practice is to achieve a total chlorine residual of about 0.5 mg/L after treatment.

The provincial objective for chlorine for the protection of fish is 0.002 mg/L or about 1/250th of the sewage treatment plant residual level. The toxic forms of chlorine, free chlorine and chloramines (chlorine and nitrogen compounds), are relatively short-lived in the receiving waterbodies but, for distances ranging from a few metres to several kilometres below a sewage treatment plant outfall, chlorine can severely affect the aquatic community.

Un-ionized free ammonia (molecular ammonia) is the toxic form of this substance. Its presence in this form is dependent upon water temperature and pH. Since warm water and alkaline conditions result in elevated un-ionized free ammonia concentrations, summer conditions are most critical for this toxicant. The provincial objective for un-ionized free ammonia is 0.02 mg/L.

Un-ionized free ammonia occurs naturally in low concentrations (0.002 mg/L)* and is present in higher concentrations in wastes discharged from sewage treatment plants (in the order of 0.5 mg/L) or direct runoff from livestock operations. It can occur at levels approaching the provincial objective (0.02 mg/L) in the deep water areas of reservoirs during the summer stratification period.

Chlorine and ammonia compounds are present, to some extent, downstream from most conventional sewage treatment facilities in the basin. Wastewater discharges from lagoons are not chlorinated and, therefore, chlorine toxicity is not a problem below these facilities. The most serious conditions exist downstream from the large sewage treatment plants serving the major population centres. Chlorine and un-ionized free ammonia from sewage treatment facilities in the Grand river basin do not affect water quality or the aquatic communities in Lake Erie.

Chlorine, ammonia and many other wastewater components cannot usually be reduced to the provincial water quality objectives in the treated effluent without large expenditures and the use of very sophisticated technology. To accommodate practical treatment limitations the mixing zone or limited-use zone concept is applied. A designated area immediately adjacent to the outfall is identified as a zone where concentrations may exceed the objectives, but on the other hand, will not be rapidly lethal to important aquatic organisms. A mixing zone should not extend across the entire stream presenting a barrier to the migration of fish and other aquatic organisms; rather, a substantial zone of passage with pollutant concentrations below the objectives is needed. Discharges from treatment plants must be designed to keep mixing zones as small as possible. Acceptable mixing zones are determined on a case by case basis, and are not used as an alternative to treatment. Ammonia, chlorine and mixing zones for major municipalities in the Grand river basin are discussed in more detail in Technical Report No. 29.

**Based on mid-summer water quality conditions in the headwater area, (Marsville), with a water temperature of 25°C and pH of 8.5.*

Suggested Remedial Measures

With expanding populations and increasing agricultural activity, efforts should be made to reduce the input of toxic substances. Farming practices should ensure that runoff from manure piles, barnyards and feedlots, as well as overland transportation of nitrogen from recently fertilized fields are minimized and not discharged directly to watercourses. Measures should be investigated to minimize the formation of un-ionized free ammonia in the deep water areas of the major reservoirs, and/or to reduce the discharge of these ammonia enriched waters to the downstream reaches.

The impacts of toxicants can be reduced but not eliminated by maximizing the efficiency of the sewage treatment plants and maintaining good operating practices. Ammonia levels can be reduced by adding nitrification facilities to the existing plants while chlorine problems could be eliminated by using a different form of disinfection or by dechlorination. Small sewage treatment facilities in the basin should be operated in a manner to minimize the input of ammonia and chlorine.

6.3.3 Objective for Ground Water Quality

The goal of the Province of Ontario for ground water water quality management as stated in "Water Management — Goals, Policies, Objectives and Implementation Procedures of the Ministry of the Environment" (Ref. 7) is to protect the ground water from any source of contamination which may affect water supplies for drinking water and agricultural uses. In addition, protection of aquatic life is a consideration in cases where ground water is a significant component of streamflow. As in the case of surface water, various criteria for specific water uses have been set to achieve this goal.

6.3.4 Problems With Ground Water Quality

Ground water quality problems can be classified into two divisions: regional and local. The main regional water quality problem is the presence of a large amount of dissolved solids, due mainly to sulphate, which occurs naturally in bedrock ground waters in the western and southern portions of the watershed. This condition often limits the use of this water for drinking water and agricultural purposes.

Man-made contamination is generally confined to specific sites and is usually of a local nature. The chief sources of contamination in the Grand river basin are old industrial land fill sites such as those located near Elmira on Canagagigue creek and at Breslau on the Grand river. Industrial chemicals from the Elmira site have seeped into the same aquifer that supplies the town with drinking water. However, no contaminants have been detected in the drinking water supply and an intensive monitoring program is being carried out to delineate the problem. The Breslau site, an abandoned land fill site containing industrial oils and solvents, has contaminated the aquifer and, until recently, the adjoining portion of the Grand river. Investigations are being carried out to determine the most efficient means of limiting or removing the contamination. At present, the leachate from the site is being contained and trucked to the Kitchener sewage treatment plant.

Increasing amounts of hydrologic, chemical and geologic data are required to identify the areas and mechanisms by which pollution enters the ground water flow system. A basic ground water quality network to monitor quality on the regional scale in the basin is being designed by the Ministry of the Environment as part of an overall provincial network. However, a more intensive network for the monitoring and surveillance of local contamination problems and water quality in specific municipal aquifers should be developed in addition to the general provincial network. Observation wells in the intensive network should be located in major municipal aquifers to provide early warning of any contamination. Particular attention should be made to monitoring aquifers located near possible sources of contaminants.

6.4 Public Perceptions of Water Management Problems

Several public involvement mechanisms were used to ensure that the basin study was addressing the main water management concerns of basin residents.

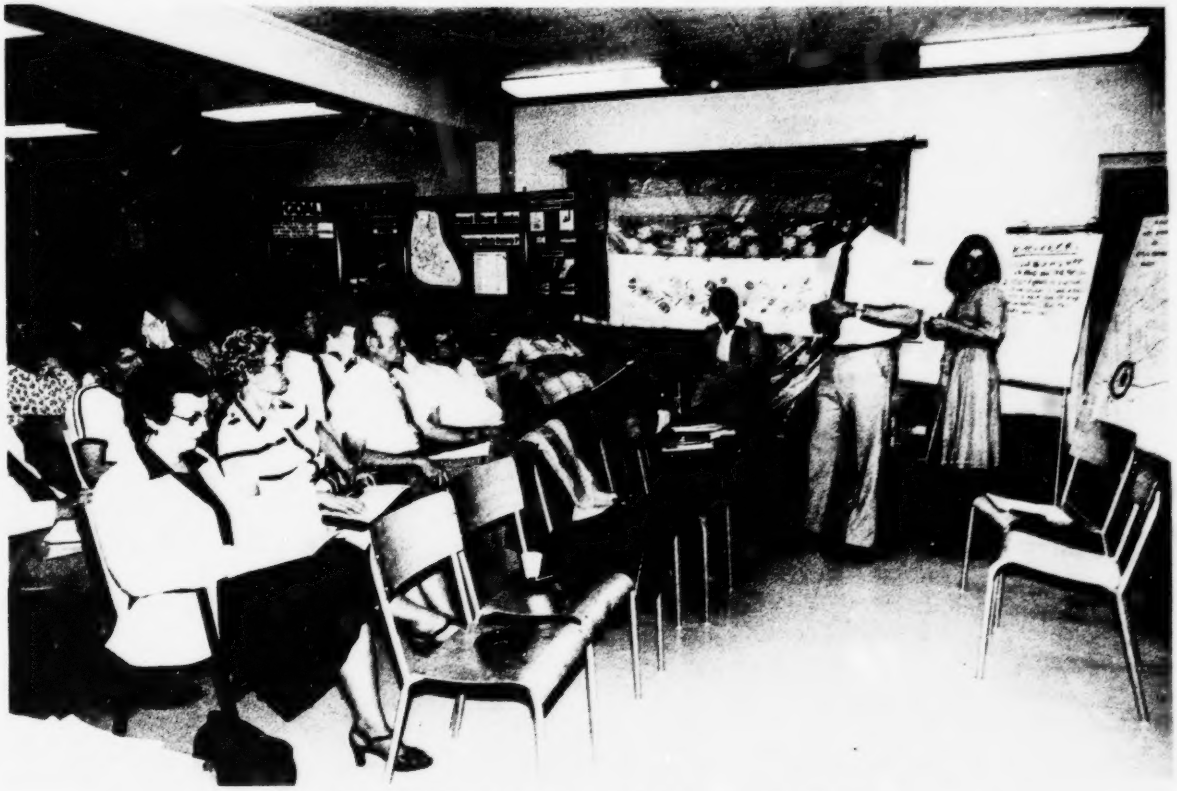
In a series of twelve public meetings held in various communities throughout the watershed in the spring of 1979, ninety-five participants ranked the five major water management concerns as:

1) water quality
2) flooding
3) water supply
4) environmental protection and conservation
5) tourism/recreation, floodplain zoning.

In a 1971 survey of 400 residents in Waterloo County, now the Regional Municipality of Waterloo, the major water management problems were ranked as follows (Ref. 12):

1) water quality
2) water supply
3) flooding.

However, public perceptions vary depending on a variety of factors including background knowledge, time of year a questionnaire survey is conducted and local events. This was evidenced by the results of a questionnaire completed by four public consultation working groups representing the upper, mid-upper, mid-lower and lower regions of the watershed, established as in-



PUBLIC MEETINGS: One of 12 held throughout the Watershed

formal groups to provide advice. The questionnaire was conducted after a year of intensive review of the basin water management problems and feasible solutions. In contrast to the previous two questionnaire results, the working groups ranked the main concerns as:

1) water supply
2) flooding, water quality (both ranked equally).

Maintaining an adequate water supply emerged as an important objective in all the regions except the upper region where supply was not perceived as a problem. In the mid-upper region, it was deemed important that the water demands of the urban municipalities do not threaten rural ground water supplies. The group referred specifically to the pumping activities of the Regional Municipality of Waterloo in Wilmot township.

All four groups described flood damage reduction as an important objective. Areas of special concern were Grand Valley in the upper region, Cambridge in the mid-upper region, Paris and Brantford in the mid-lower region, and Port Maitland in the lower region.

The group representing the upper region felt that as a minimum objective, existing water quality in the Grand river should be maintained. The group representing the mid-upper region felt that the water leaving the region should be suitable for drinking purposes for downstream municipalities. Groups from the upper and mid-upper regions questioned the need to improve water quality to support recreational activities such as swimming and sport fishing. In contrast, the group representing the lower region, where water-based recreation is of prime interest, felt that the best water quality possible should be achieved.

Of special concern in the upper region, where most of the reservoir sites are located, is the amount of agricultural land which would be removed from production or restricted in any way by the implementation of water management plans.

Generally, recreational use was of a low priority. However, in the lower region where a number of water-based recreational activities are pursued, a high priority was placed on future water-based recreation by the group representing this region (Ref. Tech. Report No. 43).

7. WATER MANAGEMENT MEASURES FOR LOCAL AREAS

The previous chapter described the major water management problems for which specific projects are required to meet the basin study objectives at a basin-wide level. Various water management plans for the Grand river basin were formed from these specific projects and are discussed in Chapter 8 and Appendix B. These plans, however, do not deal specifically with the local water management problems which should be solved to aid any water management plan in meeting the basin study objectives.

The following sections discuss flooding, water supply and water quality issues as they apply to local areas in the following river systems: upper Grand river, middle Grand river, Conestogo river, Canagagigue creek, Nith river, lower Grand river and Speed and Eramosa rivers. Projects which would contribute to solving the local problems are also described. Cost data and the staging of sewage treatment projects are based on the medium population projection for the various communities and are summarized in Table 7.2. Information relating to test drilling for additional sources of water supply in local areas is detailed in Technical Report No. 10.

7.1 Upper Grand River System

Flooding

Some flooding problems are experienced in the communities of Grand Valley and Elora. In Grand Valley, flooding occurs due to high flows or ice jamming through the central portion of the village. A $1.4 million channel works project is recommended to contain a flood having a frequency of 1 in 23 years. Elora experiences minor flooding in some recently renovated stores adjacent to the Grand river. No remedial measures are proposed, but early flood warnings are stressed.

Water Supply and Water Quality

Dundalk — The municipal water supply system consists of three bedrock wells with a combined rated capacity of 1,964 m^3/d (0.432 mgd). This supply will be sufficient to meet the average daily demand in the year 2031. Additional bedrock yield in the area is judged to be in excess of 1,309 m^3/d (0.288 mgd). Two areas presently accessible for test drilling have been identified.

Streamflows are low in the vicinity of Dundalk which dictates the necessity of seasonal discharge lagoons for sewage treatment. It is planned to expand the existing lagoon system by adding pre-aeration units and increasing the storage capacity of the lagoons. The lagoon system will then have a capacity to service 3,700 people and will be sufficient to meet 2031 medium population demands.

Grand Valley — As there is no municipal water system serving Grand Valley, residents use individual private wells. Bedrock in the area provides a good aquifer and should yield sufficient water for future population increases.

Under existing, low streamflow conditions, the treated wastewater discharged from the village's extended aeration plant results in un-ionized free ammonia levels in the river in excess of the 0.02 mg/L provincial water quality objective. The ammonia objective could be achieved during the critical summer months through increased streamflow from the Luther marsh and/or by the improvement of nitrification at the sewage treatment plant (Ref. Tech. Report No. 17). A review of streamflow regulation from the Luther reservoir is presently being undertaken. Future expansion of the sewage treatment plant in 1991 will require the installation of nitrification facilities.

Fergus — The municipal water supply system consists of five bedrock wells with a combined rated capacity of 8,018 m^3/d (1.764 mgd). This supply can meet the average daily demand projected for the year 2001. However, an additional supply of about 2,441 m^3/d (0.537 mgd) will be needed to meet the projected average daily demand, based on a medium population projection, in the year 2031. The water from the Fergus municipal wells is very hard, and exceeds drinking water criteria for iron, sulphate and total dissolved solids. While yields from bedrock tend to increase with depth, water quality may deteriorate. Additional municipal supplies may be developed in the basal sands and gravels and/or bedrock of a buried bedrock valley that runs through the north western section of Fergus. Another area recommended for test drilling in bedrock has been identified where the optimum well depth for suitable water quality appears to be approximately 70 m (225 feet).

Under low, summer streamflow conditions, the treated wastewater discharged from the conventional activated sludge plant serving Fergus and the ammonia-enriched waters from the bottom zone of Belwood reservoir discharged to the river, combine to raise on occasion, un-ionized free ammonia levels above the 0.02 mg/L objective downstream from Fergus. The ammonia objective could be achieved by:

1) operating the existing sewage treatment plant to provide some nitrification (to 4 mg/L ammonia). Any future expansion of the Fergus sewage treatment plant will require the installation of nitrification facilities
2) reducing ammonia levels in water discharged from the Belwood reservoir. Reduction in upstream ammonia levels could possibly be done by lake aeration and upstream nutrient control
3) a combination of the above (Ref. Tech. Report No. 17).

Elora — The municipal water supply system consists of two bedrock wells, with a combined rated capacity of 3,036 m^3/d (0.668 mgd). This supply can meet the average daily demand projected for the year 2001. To meet the average daily demand in the year 2031, based on a medium population projection, an additional 1,045 m^3/d (0.230 mgd) may have to be developed. Although bedrock in this area is generally considered to be a good aquifer, bedrock yields are highly variable. Test drilling for potential municipal supplies is recommended in a buried bedrock valley to the south of Elora.

The village's conventional activated sludge sewage treatment plant has been expanded recently from 380 to 3,000 m^3/d. Under present streamflow and hydraulic loading conditions, the provincial water quality objectives for dissolved oxygen and ammonia are satisfied. However, when the plant reaches its hydraulic capacity, partial nitrification of the effluent to 6 mg/L ammonia would be required to meet the instream un-ionized ammonia objective of 0.02 mg/L under current low flow conditions. This should be achievable with careful operation of the existing plant. While the increased capacity of the plant is sufficient to meet the village's growth to the year 2006, any further expansion of the Elora sewage treatment plant will require nitrification and filtration of the effluent. If the Montrose dam were constructed, the physical configuration of the stream would change, which may alter the mixing zone downstream from the sewage treatment plant. This condition could influence the assimilative capacity of the watercourse. Further assessment to determine the impact of the nutrients in and toxicity of the Fergus and Elora sewage treatment plant effluent would be required if this dam were constructed (Ref. Tech. Report No. 17).

7.2 Middle Grand River System

Flooding

Flooding in the middle Grand river basin is confined largely to those flood damage centres identified in Chapter 6 for the middle part of the Grand river basin. Although dykes have recently been installed in Kitchener (Bridgeport), there is still a slight possibility that flooding may occur if they were overtopped or breached. At West Montrose, some flooding occurs, mainly as a result of ice jams. Early flood warnings to this area are stressed. Measures to reduce flood damage in other centres in the middle Grand river basin are described in detail in Chapter 9.

Water Supply and Water Quality

Maryhill — The community is dependent largely on private domestic wells for its water supply. One subdivision with about 150 residents is serviced by one overburden well and one bedrock well operated by the Regional Municipality of Waterloo. The combined rated capacity of these wells of 327 m^3/d (0.072 mgd) should be sufficient to meet the average daily demands of the entire community in the year 2031. There is a good potential for additional ground water development in this area.

Sewage treatment is achieved by individual, private septic tank systems. No water quality problems are anticipated now or in the future.

7.3 Conestogo River System

Flooding

Flooding in the Conestogo river basin is confined mainly to Drayton where the river passes through the centre of the village. High flows cause periodic flooding to several residential blocks. Two dyking alternatives to resolve these problems are proposed at a cost of approximately $200,000.

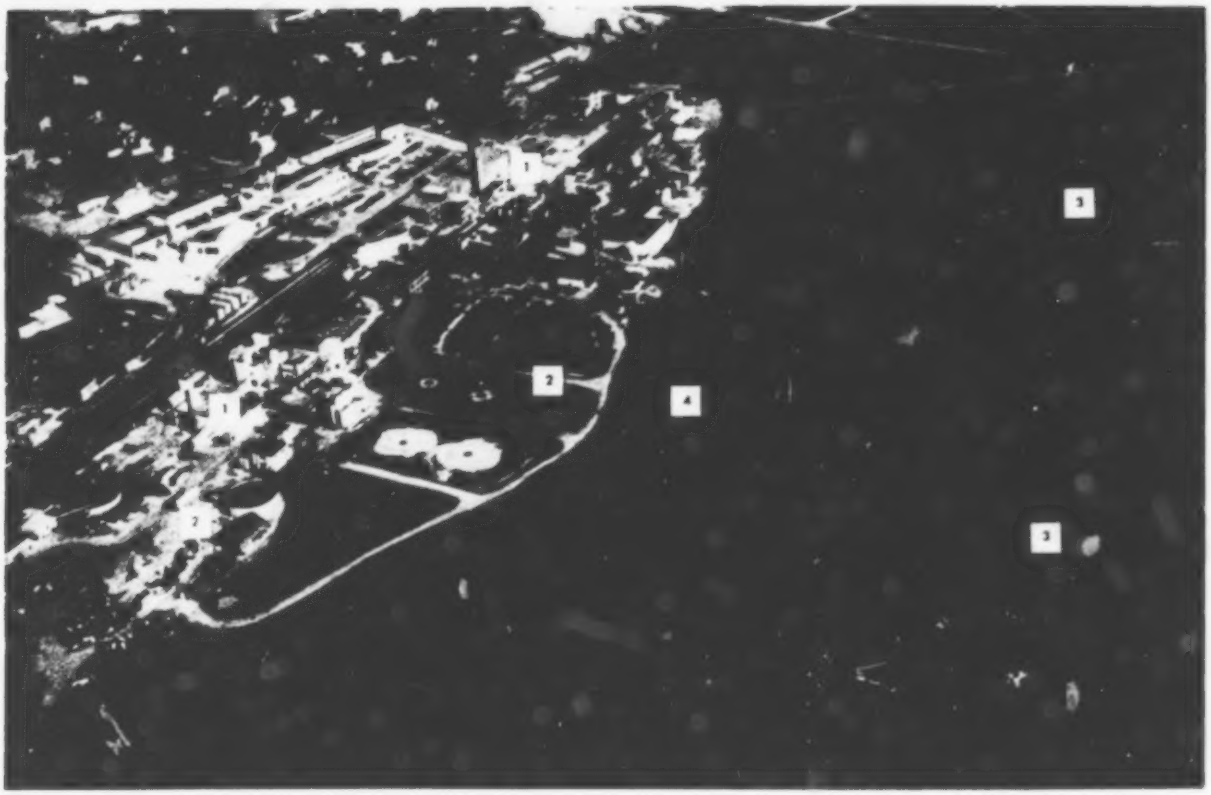
Water Supply and Water Quality

Arthur — The municipal water supply consists of five bedrock wells, with a combined rated capacity of 2,027 m^3/d (0.446 mgd), and one standby bedrock well rated at 850 m^3/d (0.187 mgd). This supply appears to be sufficient to meet the projected average daily demand in the year 2031. The Guelph formation bedrock in this area has good potential for high-yield development and there should be little difficulty in securing additional municipal water supplies. Two areas suitable for test drilling for municipal supplies have been identified.

The seasonal discharge lagoon serving the village is normally discharged very quickly during periods of high streamflow in the spring or fall and, consequently, no resultant water quality problems have been observed to date. If these high flows (spring or fall) do not occur during a very dry year, the un-ionized ammonia objective of 0.02 mg/L will not be met downstream from the lagoon. Discharge proportional to streamflow during the period October to May would assist in meeting this criteria (Ref. Tech. Report No. 19). The existing hydraulic capacity of the lagoon will service approximately 2,100 people. Depending upon population growth, this capacity will be exceeded at some point between the years 1985 and 2001.

Drayton — Village residents are now serviced by individual and communal private wells. A municipally operated system has been proposed. Ground water resources in the underlying bedrock are sufficient to meet the community's needs.

Sewage treatment is achieved through individual, private



By Kitchener-Waterloo Record

CANAGAGIGUE CREEK AT ELMIRA: Shown in the photo are (1) Uniroyal chemical complex; (2) Uniroyal industrial point treatment plant; (3) former waste disposal sites; (4) Canagagigue creek.

septic tank systems. Malfunctioning septic tanks and tile fields in the community have resulted in bacteriological contamination of the Conestogo river. The potential for contamination of ground water and thus private water supplies also exists. As a result, a municipally-operated annual discharge lagoon is currently being planned for the village. Discharge will occur in November and December to coincide with the draw-down operations of the Conestogo reservoir. By following this procedure, downstream water quality degradation should not occur (Ref. Tech. Report No. 19).

St. Jacobs – St. Jacobs shares a common ground water supply with Elmira.

Conditions in the Conestogo river downstream from St. Jacobs are acceptable at present. Further growth in the village would be contingent upon reducing ammonia levels in the sewage treatment plant effluent to 5 mg/L. This measure will ensure that the in-stream water quality objective for un-ionized ammonia of 0.02 mg/L will be met. The sewage treatment plant is currently near its hydraulic capacity and further expansion will soon be required to meet future growth.

7.4 Canagagigue Creek System

Flooding

No major flooding problems are experienced in communities situated adjacent to Canagagigue creek.

Water Supply and Water Quality

Elmira – The water supply system for Elmira-St. Jacobs consists of six overburden wells in Elmira connected via a pipeline to two bedrock wells in St. Jacobs. The combined rated capacity of 21,000 m^3/d (4.61 mgd) will be sufficient to meet the estimated average daily demand in the year 2031. An additional 3,600 m^3/d (0.79 mgd) is estimated to be available from the existing well fields.

Recent investigations have discovered that industrial organic compounds are leaching from abandoned waste disposal sites into the underlying aquifer. However, no contamination has been detected in the adjacent ground water supply wells at Elmira. Hydrogeologic investigations are presently being carried out to determine the extent of aquifer contamination and the remedial measures required to protect the drinking water supply.

Elmira is currently served by a 3,100 m^3/d (0.682 mgd) conventional activated sludge sewage treatment plant which treats both the town's municipal wastewater as well as pretreated effluent from Uniroyal Ltd. Water quality conditions in Canagagigue creek downstream from Elmira are seriously degraded, most notably by bacterial contamination and high levels of un-ionized free ammonia. Trace industrial organic compounds have also been measured in the plant's effluent and the stream. Current plans call for a plant expansion to 4,600 m^3/d (1.011 mgd) with nitrification, filtration and influent flow proportioning of town and Uniroyal wastes. With these improvements and a minimum outflow from the Woolwich reservoir of 0.28 m^3/s (10 cfs), instream un-ionized ammonia levels will be reduced from 0.08 to 0.03 mg/L and the dissolved oxygen criteria of 4 mg/L will be met (Ref. Tech. Report No. 16).

The present plant expansion will service a population of approximately 8,200 people and will accommodate growth to the year 1991. At that time, the sewage treatment plant will be utilizing the maximum assimilative capacity of Canagagigue creek. Further growth in Elmira will require the investigation of several expensive treatment alternatives such as the addition of new advanced sewage treatment; a pipeline diversion of the sewage effluent, either to the Grand river or to another sewage treatment facility such as the Kitchener or Waterloo sewage treatment plant; or a combination of the above.

7.5 Nith River System

Flooding

Flooding occurs at New Hamburg, Plattsville and Ayr. Paris, located at the confluence of the Nith and Grand rivers, also has flooding but this is usually caused by high flows on the Grand river. Flood damage reduction could be accomplished either through construction of the Nithburg reservoir or dyking and channelization. However, dyking and channelization provide a less costly and more effective solution than does a reservoir (Table 7.1). Details on flood damage reduction plans for Paris and New Hamburg have been included in the discussion of the final plans (Chapter 9).

Water Supply and Water Quality

Milverton — The water supply system for Milverton consists of two wells with a combined rated capacity of 1,432 m^3/d (0.315 mgd). This supply should be sufficient to meet the average daily demand, based on a medium population projection, in the year 2031. Additional supplies can

Table 7.1 Flood Damage Reduction on the Nith River

Flood Damage Centres	Existing Flood Damages at 6% Discount ($)	Reduction in Flood Damages by Nithburg Reservoir at 6% Discount ($)	Reduction in Flood Damages by Channel Improvement at 6% Discount ($)	Cost of Nithburg Reservoir ($)	Cost of Channel Improvements ($)
New Hamburg	362,526	220,668	362,526	24,000,000	760,000
Plattsville	17,338	14,185	17,338		50,000
Ayr	99,300	39,405	N/A		N/A
Paris	--*	--*	--*		--*
TOTAL	479,164	274,258	379,864	24,000,000	810,000+

Note:

• Paris is located at the junction of the Grand and Nith rivers. Flood damages are generally caused by the Grand river.

N/A Not Available

be obtained from two un-equipped, stand-by wells rated at 1,146 m³/d (0.252 mgd). Overburden and bedrock in the area have potential for future development, and an area recommended for test drilling has been identified.

The seasonal discharge lagoon serving Milverton is located to the southwest of the village, beyond the boundaries of the Grand river basin. It is normally discharged during the fall, winter and spring to the receiving watercourse, the Boyle Drain, which joins the Maitland river. The existing treatment lagoon was expanded in 1981 and now consists of three aerated cells and two storage cells. Assuming a medium population growth for the village, this facility should be adequate to the year 2006.

Wellesley – Water supply is based on private well supplies and one municipal communal system. The existing ground water aquifer should be adequate to meet future water demands.

Streamflow in the Nith river near Wellesley is very low, especially during the summer months. As a result, near stagnant conditions occur periodically. Treated wastewater discharges from the extended aeration plant elevates un-ionized free ammonia concentrations downstream. To solve this problem at the present plant capacity, treatment requirements would include nitrification to 5 mg/L total ammonia and a discharge rate proportional to streamflow. Expansion of the existing plant will be required by approximately 1991 to meet the medium population requirements. For any expansion of this facility, seasonal storage of the final effluent will be required during the critical summer low-flow months with discharge proportional to streamflow at other times.

New Hamburg – The water supply system for New Hamburg and Baden consists of two overburden wells in Baden, connected by pipeline to two overburden wells in New Hamburg. The combined rated capacity of 7,655 m³/d (1.684 mgd) should be sufficient to satisfy the average daily demands projected for the year 2031. A potential test-drilling area for additional municipal supplies has been identified. However, the development of the upper aquifer within this recommended area could result in interference problems with nearby Kitchener-Waterloo municipal wells and private wells in the area.

No water quality problems are being experienced in the Nith river downstream from New Hamburg. Expansion of the existing lagoon facility is presently underway. The expanded facilities will include pre-aeration, lagoons, intermittent effluent filtration (to provide nitrification), and discharge proportional to stream flow. Post-aeration may be required in the storage lagoon if hydrogen sulphide is produced. Depending upon effluent quality, this facility will serve approximately 5,000 to 6,000 people and will provide capacity to the year 2021 for a projected medium population (Ref. Tech. Report No. 18).

Baden – Baden shares a common ground water supply with New Hamburg.

Although the extended aeration plant serving Baden produces a high quality effluent, very low streamflow in Baden creek results in degraded water quality conditions below the sewage treatment plant. Poor upstream water quality aggrevates this problem.

Plattsville – The community is serviced by a water supply system of two overburden wells having a combined rated capacity of 1,700 m³/d (0.374 mgd). This supply will likely exceed projected demand in the year 2031. Additional supplies may be developed in overburden in this area.

Two storage lagoons and two aerated lagoons were installed in Plattsville in 1980 to provide sewage treatment. Effluent from the lagoons is discharged seasonally to the Nith river. This facility will serve approximately 960 people and will provide capacity to the year 2031 for a projected medium population.

Ayr – The water supply system for Ayr consists of two overburden wells with a combined rated capacity of 4,714 m³/d (1.037 mgd). This supply appears to be sufficient to meet the projected average daily demands in the year 2031. There appears to be a good potential in this area for additional ground water development, in overburden and bedrock.

A recently constructed extended aeration sewage treatment plant will serve the projected medium population for the next twenty years. Further expansion will require nitrification of the effluent. No water quality problems are experienced at present.

New Dundee – The water supply is based on private well supplies and one municipal communal system having 2 wells with a capacity of 851 m³/d (0.19 mgd).

Sewage treatment is by private septic tanks.

Paris – The municipal water supply system for Paris consists of two overburden wells and a shallow ground water collector system with a combined rated capacity of 15,181 m³/d (3.34 mgd). This supply is greater than the average daily demand projected for the year 2031. An area recommended for future test drilling appears to contain two overburden aquifers – a basal formation near the Grand river and an upper formation extending eastward to the Village of St. George.

The town is served by a 2,300 m³/d (0.506 mgd) extended aeration plant which discharges to the Grand river downstream from its confluence with the Nith river. The wastewater discharge has minimal impact on water quality in downstream reaches of the Grand river. It is expected that the present expansion of this facility to 6,900 m³/d (1.52 mgd) will provide an adequate level of treatment to the year 2031 (Ref. Tech. Report No. 9).

7.6 Lower Grand River System

Flooding

Periodic flooding occurs in the communities of Caledonia and Dunnville. Proposed flood protection measures for both areas are described in the final plans (Chapter 9).

Water Supply and Water Quality

Caledonia – The water system for Caledonia consists of five bedrock wells with a combined rated capacity of 11,637 m^3/d (2.56 mgd). This supply will be sufficient to meet the average daily demand, projected for the year 2031. The water from the Caledonia municipal wells is very hard and exceeds drinking water criteria for iron, sulphates and total dissolved solids. Two areas recommended for test drilling for additional municipal supplies have been identified.

Caledonia is served by a 2,300 m^3/d (0.506 mgd) conventional activated sludge sewage treatment plant which will service approximately 5,000 people. The plant is almost at capacity and will soon require an expansion. No significant water quality problems are experienced below Caledonia. It is expected that the conventional waste treatment will be sufficient for future expansions.

Cayuga – The community of Cayuga uses the Grand river as its source of water supply. Future water supply shortages are not anticipated.

The community is served by a 900 m^3/d (0.198 mgd) extended aeration sewage treatment plant which will service approximately 2,000 people. This facility should be adequate until the year 2006, when an expansion will be necessary. The present level of waste treatment will be sufficient for expansions to serve the projected population, since no significant water quality problems are experienced below Cayuga.

Dunnville – The town extracts its water supply from Lake Erie through an offshore intake located to the west of the mouth of the Grand river. The quantity and quality of supply present Dunnville with no problems now or in the future.

Dunnville is served by a 7,700 m^3/d (1.69 mgd) conventional activated sludge sewage treatment plant. This facility will be adequate to meet the projected sewage demands to the year 2031. At present, no significant water quality problems are experienced below Dunnville.

St. George – The municipal water system of St. George consists of one flowing overburden well, rated at 8,182 m^3/d (1.80 mgd). This supply will likely exceed the average daily demand projected for the year 2031. There appears to be a good potential for additional municipal supply development in overburden in the St. George area. A recommended test-drilling area has been identified.

A recently constructed extended aeration sewage treatment plant with a capacity of 1,100 m^3/d (0.24 mgd) will serve a population of about 2,500 people to about the year 2015. Provision has been made for effluent storage if it is required. Streamflows are very low in Fairchild creek, the receiving watercourse, and as a result effluent storage and seasonal discharge may be required.

7.7 Speed and Eramosa Rivers System

Flooding

Minor flooding during spring breakup occurs in Rockwood and Eden Mills as a result of ice jamming and at the junction of the Grand and Speed rivers under flows exceeding those of the 50-year flood. No remedial measures are proposed but early flood warnings are stressed.

Water Supply and Water Quality

Rockwood – The municipal water supply system for Rockwood consists of two bedrock wells with a combined rated capacity of 3,927 m^3/d (0.86 mgd). Bedrock ground water in this area is hard but generally of good chemical quality. The present supply will be sufficient to meet expected demand in 2031. Additional supplies with expected well capacities in excess of 1,309 m^3/d (0.288 mgd) may be developed from the bedrock.

Sewage from the community of Rockwood is directed to the Guelph sewage treatment plant for treatment. As a result, water quality in the Eramosa river is not significantly affected by wastewater discharges from this community. This system can service up to 1,770 residents and should suffice to about the year 2001 if a medium population growth were realized.

7.8 Municipal Sewage Treatment Costs For Local Areas

The costs, treatment descriptions and staging of treatment for various local areas within the basin are summarized in Table 7.2. Future costs were discounted to give their present value to the base year 1980 (Appendix C). Costs were based on a 6 percent discount rate and the medium population growth rate. The only advanced treatment considered was nitrification and filtration. At some point in the future, as noted in Table 7.2, Elmira will require the examination of more advanced treatment alternatives in order to satisfy the receiving stream water quality criteria.

Table 7.2 Municipal Sewage Treatment Costs for Local Areas

(Present Values of Costs in Millions of 1979 Dollars at 6% Discount)

		Current Treatment		Additional Treatment Required		Costs			
River Basin	Municipality	Type	Expansion Date	Type	Date Required	Capital	O & M	Total	Comments
Upper Grand River	Dundalk	Lagoon	1986	Pre-Aeration	1986	0.93	0.24	1.17	Additional treatment required after 2011.
	Grand Valley	Extended Aeration	1991	Nitrification	1991	0.63	0.96	1.59	
	Fergus	CAS-P	1996	Nitrification Dual Media Filtration	1996	0.93	1.96	2.89	
	Elora	Extended Aeration	2006	Nitrification Dual Media Filtration	2006	0.48	1.43	1.91	
Conestogo River	Arthur	Lagoon	--		--	--	0.25	0.25	— (Additional treatment required between 1985-2001)
	Drayton	Septic Tanks		Lagoon	1981	1.4	0.22	1.62	
	St. Jacobs	Extended Aeration	1986-1996	Nitrification	1986-1996	0.70	1.00	1.70	
Canagagigue Creek	Elmira	CAS-P	1982	Nitrification Dual Media Filtration	1982	1.62	1.67	3.29	Additional treatment or diversion required by 2006.
Nith River	Wellesley	Extended Aeration	1991	Storage, Intermittant Sand Filtration	1991	0.73	0.86	1.59	Existing facilities will provide capacity to the year 2021.
	New Hamburg	Pre-Aeration, Lagoon Intermittant Sand Filtration	--	--	--	--	1.26	1.26	
	Baden	Extended Aeration	--	--	--	--	0.76	0.76	
	Ayr	Extended Aeration	2006	--	--	0.28	0.94	1.22	
	Plattsville	Aerated Lagoon					0.25	0.25	
Lower Grand River	Caledonia	CAS-P	1983	--	--	1.77	1.70	3.47	
	Cayuga	Extended Aeration	2006	--	--	0.24	0.89	1.13	
	Dunnville	CAS-P	--	--	--	--	2.48	2.48	
	St. George	Extended Aeration	--	--	--	--	0.92	0.92	

- All costs and staging of projects are based on a medium population projection (Ref. Tech. Report No. 12)

8. FORMATION AND SCREENING OF WATER MANAGEMENT ALTERNATIVES

8.1 Water Management Plans

Initially, the formation of various water management alternatives began by identifying a range of proposed structural and non-structural water resource projects which could contribute to achieving the basin study's objectives to: reduce flood damages; ensure adequate water supplies; and maintain adequate water quality.

These projects were combined to form alternative plans which were evaluated using simulation models to determine effects such as flood damage reduction and dissolved oxygen improvement. The plans were also evaluated economically by two models — a linear programming model and an inter-active decision-making model (Ref. Tech. Report No. 22). The latter was a cost-benefit model where the user stated the various plan descriptions and water quality constraints and the model produced costs, benefits and staging of projects. With the aid of these models, twenty-six alternative water management plans were produced and evaluated (Appendix B).

The plans incorporated various methods of reducing flood damages ranging from dyking, channelization, and flood control reservoirs to floodplain acquisition and floodplain zoning. Several methods were considered for meeting future water needs including development of new ground water sources, ground water recharge schemes, pipelines from river and lake sources, and reduction in water use through the application of water conservation methods. Projects investigated to improve water quality included advanced sewage treatment and flow augmentation.

Two of the plans considered what the consequences to urban growth would be if there were no additions to major sewage treatment plants or water supply facilities (Appendix B, plans 7A and 7B). With no flood damage reduction measures being recommended in these plans, they represent the study's "do nothing plans".

The first "do nothing" plan examined the implications of not constructing new sewage treatment facilities, and of not allowing the provincial water quality objectives to degrade further (plan 7A). Although this plan is the cheapest of all plans investigated, growth would be curtailed immediately at Kitchener, Waterloo and Guelph because of existing violations of the provincial water quality objectives. For a medium population projection, growth would be limited in Cambridge by the year 2021 and in Brantford by the year 2031, when the existing sewage treatment plant capacities would be exceeded.

The second "do nothing" plan examined the implications of not constructing new sewage treatment facilities and of not utilizing new water supplies (Plan 7B). Water quality in this plan would deteriorate. Because of water supply shortages, urban growth for a medium population projection would be limited in Kitchener and Waterloo by the year 1991, in Cambridge by the year 2021 and Brantford and Guelph by the year 2031. These dates could be prolonged approximately five to ten years through the use of water conservation methods.

8.2 Screening of Water Management Plans

In order to reduce the twenty-six plans to a manageable number for detailed analyses, a preliminary screening of the water management plans was carried out. This screening process consisted of a series of evaluations which eliminated less optimal plans from further consideration. The preliminary screening was carried out by: (1) comparing how satisfactorily each plan fulfilled the objectives; (2) comparing plan costs; and (3) comparing environmental and social impacts. The evaluation was done by giving a grading of very good, good, fair and poor to each plan in relation to objectives, costs, and impacts (Appendix B).

Each plan's effectiveness in achieving the basin study objectives was determined by using the following measures of benefits. The reduction in average annual flood damages was used to measure each plan's flood control benefits and the principle of consumer surplus was used to estimate the economic benefits of water supply expansions (Appendix C). A water quality index based on dissolved oxygen levels developed specifically for the basin study, was used to assess water quality benefits in the preliminary screening (Sec. 10.2; and Appendix E). The environmental and social impacts for each plan were graded using the results of a specially designed questionnaire completed by technical members of the study and analysed using a multi-criteria method (Appendix B).

8.3 Plan Selection

After the twenty-six alternative plans were evaluated by the screening process, the plans were reduced by the following three-stage process:

(1) selection of plans from a Plan Evaluation Matrix, using a multi-criteria method
(2) selection of plans by the Basin Technical Study Team using a voting analysis technique
(3) selection of plans by the Grand River Implementation Committee after evaluating the results of steps 1 and 2 and the recommendations from the public consultation working groups (Appendix B).

This process led to the selection of four main plans for detailed evaluations. Several options associated with three of the plans were also evaluated.

A detailed description of the main plans is provided in Chapter 9.

The main features of the four plans and their options are summarized below:

Plan A

Dykes and channelization, advanced sewage treatment, local sources of water supply.

Option 1 — new ground water supplies for Cambridge
Option 2 — Cambridge water system connected to the Mannheim recharge scheme at Kitchener
Option 3 — Everton reservoir added to improve water quality on the Speed river
Option 4 — protection of the Montrose reservoir site from development should it become necessary to construct the reservoir in the future.

Plan B

Montrose multi-purpose reservoir, advanced sewage treatment, local sources of water supply.

Option 1 — reservoir only — no dyking or channelization at principal flood centres
Option 2 — reservoir with dykes and channelization.

Plan C

Single-purpose dam for flood control, advanced sewage treatment, local sources of water supply.

Option 1 — St. Jacobs dam
Option 2 — Montrose small dam
Option 3 — Montrose large dam.

Plan D

Lake Erie water pipeline, advanced sewage treatment, dykes and channelization.

9. DESCRIPTION OF MAIN PLANS

This section provides detailed information on the four main water management plans selected for further evaluation. Only major basin problems and their interdependent solutions are considered in describing the main plans. Chapter 10 outlines the effectiveness of each plan in meeting basin study objectives. The plan descriptions focus on flood damage reduction measures, water quality requirements, water supply requirements, dollar value of costs of the major remedial measures and environmental and social impacts. Certain water management practices such as floodplain zoning or non-point source controls which are common to all the plans are discussed separately rather than repeated under each individual plan description.

Each plan's economic impacts are measured over a fifty year planning period (from 1980 to 2031). Since the economic impacts of a plan do not occur all at once, a discounting procedure was used to compare each plan's economic impacts on a similar basis (Appendix C). Future costs were discounted to give their present value for the base year 1980. Discount rates of 0, 6 and 10 percent were used to see how sensitive the economic impacts are to changes in the discount rate. For the individual plan components described in the following sections, costs are based on a 6 percent discount rate and the medium population growth rate. Costs for other population projections and discount rates are given in Appendix B.

9.1 Plan A — Dykes and Channelization, Advanced Sewage Treatment, Local Sources of Water Supply

Plan A utilizes dykes and channelization for flood damage reduction in the centres of New Hamburg, Cambridge, Paris, Brantford, Caledonia and Dunnville and advanced sewage treatment at Kitchener, Waterloo and Guelph for improving river water quality. Four options are considered for this plan. Plans A1 and A2 are water supply options. Plan A1 utilizes new ground water supplies for Cambridge and plan A2 connects Cambridge to a supply from the Regional Municipality of Waterloo's Mannheim recharge scheme. Plan A3 incorporates the components of plan A1, but also includes the construction of the Everton dam and reservoir on the Eramosa river to improve downstream water quality on the Speed river by augmenting summer flows. Plan A4 is the same as plan A1 except that it protects the Montrose reservoir site for future possible water management use by acquiring the land as it becomes available and by various planning controls. The components of plan A are shown on Figure 9.1.

Flood Damage Reduction

The dyking and channelization projects proposed for the six major flood damage centres in plan A would provide protection for a flood having a return period greater than one hundred years and an elevation less than or equal to the regional storm floodline. The costs of these projects are shown in Table 9.1.

DYKES: Recently completed dykes at Bridgeport on the Grand river

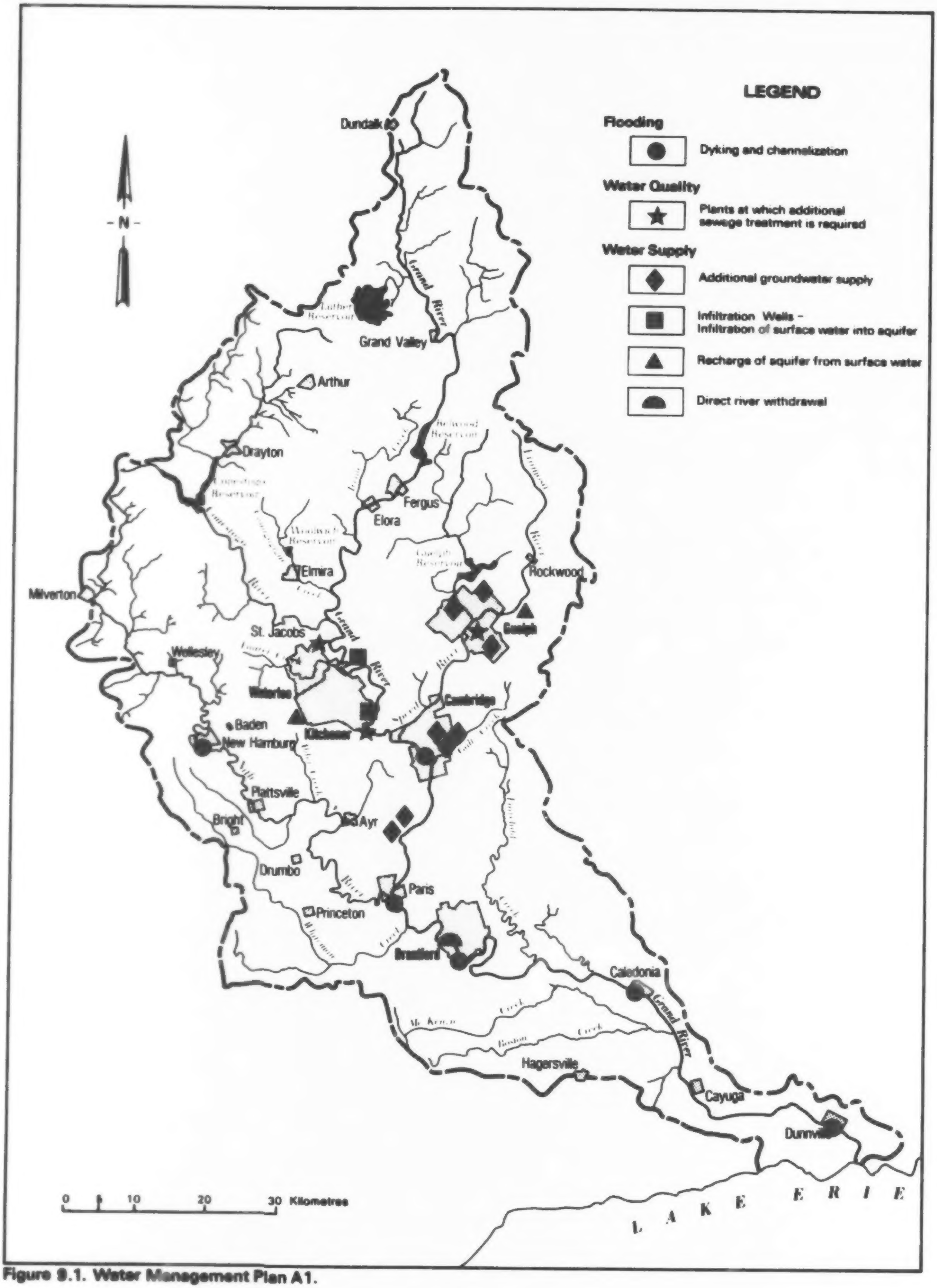

LEGEND
Flooding
Dyking and channelization
Water Quality
Plants at which additional sewage treatment is required
Water Supply
Additional groundwater supply
Infiltration Wells - Infiltration of surface water into aquifer
Recharge of aquifer from surface water
Direct river withdrawal
N
Dundalk
Luther Reservoir
Grand River
Grand Valley
Arthur
Belwood Reservoir
Drayton
Conestogo Reservoir
Fergus
Elora
Woolwich Reservoir
Elmira
Guelph Reservoir
Rockwood
Milverton
St. Jacobs
Guelph
Wellesley
Waterloo
Cambridge
Baden
Kitchener
New Hamburg
Plattsville
Bright
Ayr
Drumbo
Paris
Princeton
Brantford
Caledonia
McKenzie Creek
Boston Creek
Hagersville
Cayuga
Dunnville
0 5 10 20 30 Kilometres
LAKE ERIE

Figure 9.1. Water Management Plan A1.

Table 9.1 Costs for Flood Protection Measures Included in Plan A (Present Value of Costs in Millions of 1979 Dollars at 6% Discount)

Flood Damage Centres	Flood Protection Measures By Plan A	Date Req'd	Cost* of Measures ($)
Cambridge (Galt)	Dykes & Channelization	1981	8.50
Cambridge (Preston)	Dykes	1981	0.90
Paris	Dykes & Channelization	1981	5.30
Brantford	Dykes	1981	6.40
Caledonia	Dykes	1981	0.85
Dunnville	Dykes	1981	1.20
New Hamburg	Dykes	1981	0.80
Total			23.95

* Cost of flood protection measures primarily capital costs; operating and maintenance (O&M) costs are less than 1% of capital costs.

Water Quality Requirements

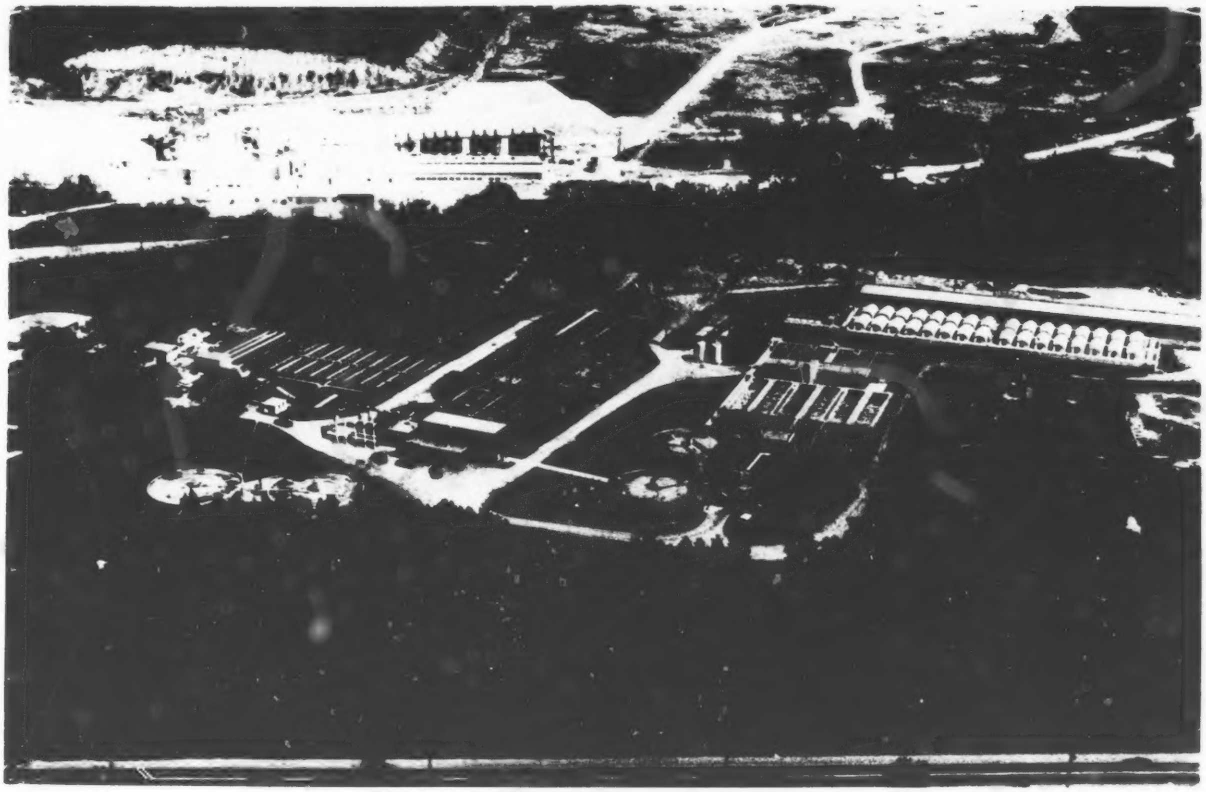
With existing conventional wastewater treatment and streamflow management practices, dissolved oxygen concentrations in the central Grand river fall during some summer months to levels that are not in compliance with the provincial water quality objective of 4 mg/L. The area most seriously affected extends from Kitchener downstream to a point just north of Paris. In addition, un-ionized free ammonia concentrations exceed the 0.02 mg/L objective in the river immediately downstream of the Kitchener sewage treatment plant and are at the objective downstream from the sewage treatment plant outfall. Residual chlorine levels within the central Grand river currently meet the water quality objective of 0.002 mg/L.

Plan A would require the immediate addition of nitrification and filtration facilities at the Kitchener sewage treatment plant to limit both the oxygen-demanding and toxic ammonia characteristics of its effluent.

Conventional activated sludge treatment and phosphorus removal is currently sufficient at Waterloo. However, as the population grows, un-ionized ammonia levels in the river downstream from the sewage treatment plant will increase. To limit the effects of toxic ammonia in the discharge, plan A would require the installation of nitrification facilities in Waterloo at the time of the next hydraulic expansion in the year 2001.

Future treatment options on the Speed river will depend to a large extent upon the effectiveness of the recently installed nitrification and filtration facilities at Guelph [rotating biological contactors (RBCs) plus sand filtration] in removing phosphorus and ammonia from the effluent. The use of rotating biological contactors with effluent filtration is new in Ontario; therefore, the effectiveness of treatment and the impact on river water quality will have to be carefully assessed over the next few years. Additional treatment to further reduce ammonia levels and steps to reduce phosphorus loadings that will in turn result in reduced aquatic growth may be required in the future. Two alternatives for additional removal at Guelph were investigated by the basin study. The first alternative consisted of chemical treatment of the RBC effluent and modifications to the existing dual-media filter. The second, more costly alternative consisted of chemical treatment of the RBC effluent plus the installation of a deep bed multi-media filter before the existing filter. Detailed pilot studies are required to determine the most cost-effective alternative. In order to achieve a conservative cost estimate, the second alternative was incorporated into plan A as the means to remove additional phosphorus at Guelph.

The levels of chlorine in the effluent at the Guelph sewage treatment plant currently meet the provincial water quality objective of 0.002 mg/L, but as the city grows and effluent loadings increase, chlorine will exceed the objective during the winter months by the year 2001.



GUELPH SEWAGE TREATMENT PLANT: Recently installed rotating biological contactors and dual-media filters are in background

Dechlorination facilities may also be required at Guelph at the time of the next hydraulic expansion.

Although no advanced treatment facilities are required at the Cambridge (Galt, Preston, Hespeler), Paris and Brantford sewage treatment plants to improve water quality, expansions at most of these plants are necessary in the future as populations grow to maintain existing effluent standards. The Galt, Preston, Hespeler and Paris sewage treatment plants have relatively small discharges which do not have significant impacts on downstream dissolved oxygen levels or create toxic ammonia problems. At Cambridge, conventional treatment expansions of the existing facilities should be adequate to meet future population demands. At Paris, the existing extended aeration plant is currently being expanded and no additional treatment will be required in the future.

The Brantford sewage treatment plant discharges its treated waste to an area of the river with a high assimilative capacity and streamflow and low levels of aquatic plant and algae growth. The city's conventional activated sludge treatment should be sufficient throughout the 50-year planning period. However, treated wastes from the Brantford sewage treatment plant mix very quickly across the entire river and a mixing zone cannot be established. The provincial water quality objective for ammonia is today achieved within a few hundred metres downstream of the outfall but as the city grows and treated wastewater loadings increase, toxic ammonia levels will exceed the objective for distances up to 2.5 km below the outfall. Chlorine is diffused to concentrations below the provincial objective and does not appear to present a problem now or in the future.

Field investigation will be required to determine if ammonia creates a barrier to the free upstream-downstream movement of fish and other aquatic life. Such investigations should also determine if a mixing zone with an adequate zone of passage can be created by realignment of the sewage treatment plant outfall structure or if nitrification facilities are required at the sewage treatment plant.

The costs and staging of advanced sewage treatment as proposed in plan A are shown in Table 9.2. The costs have been divided into current treatment costs and additional treatment costs. Current treatment costs reflect the cost of maintaining the existing effluent standards, while additional treatment costs reflect the cost of improving the existing water quality.

Table 9.2 Municipal Sewage Treatment Requirements for Plan A (Present Value of Costs in Millions of 1979 Dollars at 6% Discount)

	Current Treatment				Additional Treatment Required				Total Costs		
		Expansion		Total O&M Costs ($)			Costs				
Municipality	Type	Date	Capital Costs ($)		Type	Date Req'd	Capital ($)	O&M ($)	Capital ($)	O&M ($)	Total ($)
Waterloo	CAS-P	2001	2.46	10.38	Nitrification Filtration	2001	2.03	0.95	4.49	11.33	15.82
Kitchener	CAS-P	2021	0.93	18.61	Nitrification Filtration	1981	12.59	2.99	13.52	21.60	35.12
Guelph	RBC Filtration	1996	10.16	16.88	Chemical* Treatment & Multi-Media Filtration	1981	6.34	4.63	16.50	21.51	38.01
Hespeler	High Rate CAS-P	2026	0.33	2.84					0.33	2.84	3.17
Galt	CAS-P	2006	1.59	8.98					1.59	8.98	10.57
Preston	CAS-P	2022	0.09	4.33					0.09	4.33	4.42
Paris	Extended Aeration	1981		2.16						2.16	2.16
Brantford	CAS-P	2026	0.43	13.82					0.43	13.82	14.25
TOTAL			15.99	78.00			20.96	8.57	36.95	86.57	123.52

* The addition of chemical treatment and multi-media filtration is conditional on the evaluation of new treatment facilities recently added at the Guelph sewage treatment plant.

Water Supply Requirements

Water supply schemes for the major urban areas under plans A1 and A2 are described in Table 9.3. The most pressing water supply problem occurs in the Kitchener-Waterloo area where future water shortages will be experienced unless the existing ground water supply is supplemented. New supplies would be obtained through the use of infiltration wells located adjacent to the Grand river and the recharging of the Mannheim aquifer with water from the Grand river. In the Mannheim ground water recharge scheme, the ground water aquifer serves as an economical, underground reservoir.

The supply for the City of Cambridge would be augmented by either utilizing new ground water supplies in the Townships of Puslinch and South Dumfries (plan A1), or by expanding the Mannheim recharge project to include Cambridge (plan A2).

Guelph's future water needs would be met by obtaining new ground water supplies in the year 2011 and by expanding the existing Arkell ground water recharge scheme in the year 2021. At present, ground water at Arkell is recharged with water from the Eramosa river. Brantford would continue to depend upon the Grand river as a future source of water supply.

Environmental Impacts

Plans A1 and A2 have a variety of effects on the terrestrial and aquatic environments in the basin.

With dyking and concrete flood wall construction in various flood damage centres, the character of the river banks and the original aquatic communities in the river channel would be altered, at least temporarily, affecting the present and intended uses of the area. In some areas, river bank vegetation may have to be removed during construction. If dyking projects are restored as a parkland/walkway system, the area can be aesthetically attractive and used as open space.

The municipal sewage treatment requirements of plan A would cause negligible impacts on the terrestrial environment since the only land affected would be that acquired for plant expansion. The impact of advanced treatment on the aquatic environment, particularly in the middle Grand river would be beneficial, increasing dissolved oxygen levels and creating a better habitat for warm water aquatic life — most notably sport fish such as smallmouth bass.

The development of new ground water resources for the urban centres may result in a lowering of the water table in the surrounding areas and may affect the ecological

Table 9.3 Water Supply Requirements and Costs for Plan A*
(Present Value of Costs in Millions of 1979 Dollars at 6% Discount)

Option	Municipality	Current Source of Water Supply	Approx. ** Date When Additional Capacity is Req'd	Source of New Supply	Present Value Costs at 6% Discount	
					Capital $	O&M $
A1	Kitchener-Waterloo	Ground Water and Induced Infiltration	1981 - 1986	Expansion of Induced Infiltration	1.10	0.30
			1991 - 2001	Mannheim	8.10	0.40
	Cambridge	Ground Water	1986 - 2001	Ground Water	2.00	0.10
			2021	Connect to K-W	0.10	0.00
	Guelph	Ground Water and Arkell Recharge	2011	New Ground Water	0.09	0.02
			2021	Expanded Arkell Recharge	0.02	0.01
	Brantford	River Water	1996	Expansion of River Supply	1.50	0.43
	Total				12.91	1.26
A2	Kitchener-Waterloo	Ground Water and Induced Infiltration	1981 - 1986	Expansion of Induced Infiltration	1.10	0.30
			1991 - 2001	Mannheim	8.10	0.50
	Cambridge	Ground Water	1986	Connect to K-W	0.70	0.00
	Guelph	Ground Water and Arkell Recharge	2011	New Ground Water	0.09	0.02
			2021	Expanded Arkell Recharge	0.02	0.01
	Brantford	River Water	1996	Expansion of River Supply	1.50	0.43
	Total				11.51	1.26

* Water supply costs are the same for Plans B and C.

** Additional capacity may be required at some point within 5-year interval prior to date listed.

balance. These effects should be carefully monitored if those source areas which are designated as environmentally sensitive areas are developed for future water supply. The induced infiltration sites and artificial recharge pits which are under investigation are located in uncultivated floodplain lands and gravel pit areas. The amount of water which can be extracted from the Grand river will be regulated so that adequate water quality conditions are maintained.

Social Impacts

Besides improving water quality in the Grand and Speed rivers and creating new opportunities for water-based recreational pursuits, advanced treatment in sewage treatment plants would have minimal social impacts.

For dyking and channelization projects, temporary construction inconveniences such as noice, dust and traffic could occur. Existing water and land uses could also be disrupted or destroyed. Consequently, the location of archaeological artifacts should be monitored during dyke construction. As well, dykes may have a negative visual impact especially when they are constructed to a height which obstructs the view of the river from nearby properties. As dyking projects are not land extensive, and in many cases riverbank land is owned by a public agency, land acquisition for dykes is minimal. Because of their visibility, dykes may falsely convey a sense of security to those protected since there is always a potential risk of overtopping.

Total Costs of Plans A1 and A2 — Dykes and Channelization, Advanced Sewage Treatment, Local Sources of Water Supply

The capital and operation-maintenance costs for plans A1 and A2 are summarized in Table 9.3A. Costs are in millions of 1979 dollars and are discounted at 6%. Total costs are given with and without the cost of existing sewage treatment plant expansions. The latter cost includes the cost of expanding treatment capacity to maintain the existing effluent standards and must be incurred irrespective of the selection of a water management plan. The exclusion of these costs from the total costs better reflects the additional costs necessary to improve water quality.

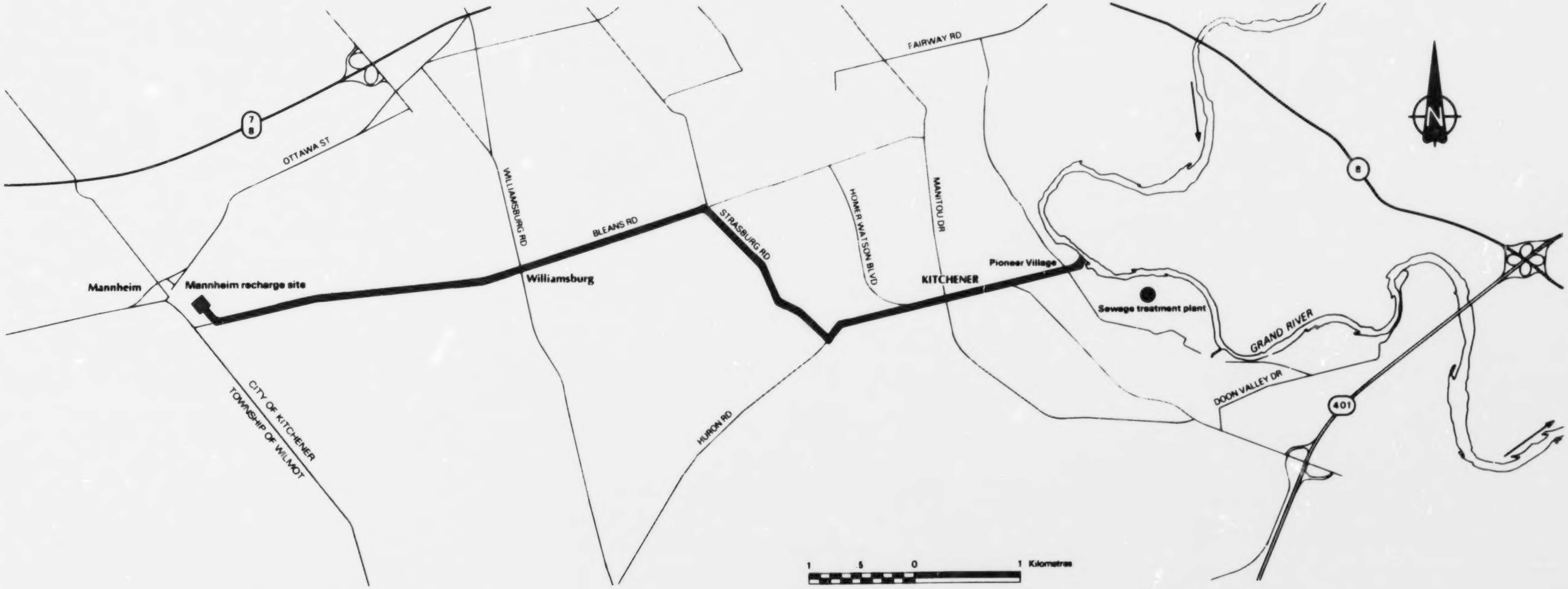
Table 9.3A Total Costs of Plans A1 and A2

Plan	STP Expansion at Current Treatment Level ($)	Additional Treatment ($)	Water Supply ($)	Flood Protection Measures	Total ($)	Total Without STP Expansion ($)
				Dyking and Channelization ($)		
A1	93.99	29.53	14.17	23.95	161.64	67.65
A2	93.99	29.53	12.77	23.95	160.24	66.25

MANNHEIM GROUNDWATER RECHARGE SITE →

Recharge site
Kitchener

View of Mannheim recharge site looking north


7
8
OTTAWA ST
WILLIAMSBURG RD
BLEANS RD
STRASBURG RD
HOMER WATSON BLVD
MANITOU DR
FAIRWAY RD
Mannheim
Mannheim recharge site
Williamsburg
KITCHENER
Pioneer Village
Sewage treatment plant
GRAND RIVER
8
N
DOON VALLEY DR
401
HURON RD
CITY OF KITCHENER
TOWNSHIP OF WILMOT
1 .5 0 1 Kilometres

Proposed pipeline route for pumping surface water from the Grand River to the Mannheim recharge site

Plan A3 — Everton Reservoir

Plan A3 is the same as plans A1 and A2 except that it provides for the construction of the Everton dam and reservoir on the Eramosa river upstream from Guelph to provide flow augmentation during the summer low flow period thereby improving water quality in the Speed river.

The cost of the Everton reservoir is $17 million and the reservoir would be required immediately. This option could also be included in plan, B, C or D.

Environmental Impacts

The reservoir and acquisition area would affect 1,275 ha (3,150 acres) of land, of which approximately 646 ha (1,600 acres) is presently used as cropland (Table 9.4).

Lowland mixed cedar forest makes up 84 percent (409 ha) of the area to be flooded. It provides excellent habitat for wildlife as it forms part of a lengthy wooded corridor along the Eramosa river. It is classified as an Environmentally Sensitive Area by the Ministry of Natural Resources. Loss of this habitat due to flooding would result in decreased diversity of flora and fauna, and would create a barrier to north/south plant and animal movement.

The upper Eramosa river valley is predominantly a natural discharge wetland. Extremely high quality water provides habitat for a well-balanced aquatic ecosystem including brook (speckled) trout. Reservoir flooding would increase temperatures at the site, and result in degraded quality due to plant decay in the new reservoir. Between one-third and one-half of existing trout habitat would be destroyed. Largemouth bass or rainbow trout could be stocked in the reservoir. However, bass may not survive the over-wintering period, and rainbow trout would compete with brook trout upstream of the reservoir for spawning territory. From the examination of the other reservoirs in the basin, it is possible that water in the river downstream of the Everton reservoir could contain elevated levels of ammonia nitrogen and water temperatures would be warmer when compared to pre-reservoir conditions. These phenomena would exist for a few kilometres downstream from the reservoir site but would not impact on the lower river.

Social Impacts

There are twenty-seven homes and two cottages in the acquisition area. Transportation effects would be minor, requiring one road re-routing and improvement of a bridge on Highway 25.

Total Costs of Plan A3 — Everton Reservoir

The costs for plan A3 are the same as plan A1 except that the discounted capital costs are increased by $16 million because of the Everton reservoir. Costs in millions of 1979 dollars are summarized in Table 9.4A. The costs are discounted at 6 percent.

Table 9.4 Lands Affected by the Everton Reservoir

(Figures in parentheses refer to hectares presently used as cropland)

Agricultural Capability	Flooded Area (ha)	Acquisition Area (ha)
Class 1 to 3	80.9	870.1
Other	404.7	404.7
Total Area Affected	485.6 (53)	1,274.8 (647)

Table 9.4A Total Costs of Plan A3 — Everton Reservoir

Plan	STP Expansion at Current Treatment Level ($)	Additional Treatment ($)	Water Supply ($)	Flood Protection Measures		Total ($)	Total Without STP Expansion ($)
				($) Everton Reservoir	Dyking & Channelization ($)		
A3	93.99	29.53	14.17	16.00	23.95	177.64	83.65

Plan A4 — Preservation of Montrose Reservoir Lands

Plan A4 is the same as plans A1 and A2 but adds the option of using the Montrose reservoir site in the future if water quality or water supply problems require the construction of the dam.

The preservation of the Montrose reservoir lands for possible future water management needs could be accomplished by any one of the following land use controls:

a) purchase of land from willing sellers
b) Ministry of Municipal Affairs and Housing zoning order preserving the land for agricultural uses only
c) local municipal zoning regulations preserving the land for agricultural uses only
d) expropriation of lands
e) combination of the above methods.

Methods b) or c) would not involve any increase in plan costs over plan A1. However, plan costs would increase over plan A1 by varying degrees if one of methods a), d), or e) was adopted. In order to obtain a plan cost estimate of plan A4, the basin study selected method a), the purchase of land from willing sellers, as the method to preserve the site for future use. At present, the Grand River Conservation Authority owns about one-third of the 1,214 hectares (3,000 acres) required to protect the site. The value of this land is estimated at $3.4 million. It was assumed that the remaining two-thirds of the property would be obtained by the year 2001. Subsequently, the land would either be sold, used for construction of a dam and reservoir or preserved for other uses.

For estimating purposes only, it was assumed that if the dam was not built in the year 2001, the land would be sold, resulting in a net cost of $4 million at a 6 percent discount rate. If the dam was built in the year 2001, the plan costs would be increased an additional $11 million at a 6 percent discount rate over the land selling option.

Environmental Impacts

For plan A4, a minimum acquisition area of 1,212 ha (3,000 acres) would be acquired. Approximately 65 percent of this area is presently being used for agriculture. Since it was assumed that no dam would be constructed, agricultural land use could be maintained and environmental impacts would be similar to those described for plan B2.

Social Impacts

The main social impact of plan A4 is that it does not remove the element of uncertainty for Montrose area property owners as to the future land use of their particular property. If zoning is implemented with land acquisition, property owners within the zoned area may find that the value of their land would increase less rapidly because of restricted development prospects. Without the implementation of specific zoning, the acquisition of land tends to raise land prices at the reservoir site.

With the land acquired and/or zoned for protecting the dam site, some decrease in agricultural production may be observed as a result of poor management practices by a few owners and tenants. This impact can be avoided where land is acquired by the Grand River Conservation Authority, since the Authority would require the tenant to use proper agricultural land management practices. The social impacts for a reservoir constructed in the future are the same as for plan B2 (Sec. 9.2.).

Total Costs of Plan A4 — Preservation of Montrose Reservoir Site

The costs for plan A4 are the same as plan A1 except that the discounted capital costs are increased by $4 million for option (i), purchase and disposal of the reservoir lands, and $15 million for option (ii), construction of the reservoir. Costs in millions of 1979 dollars are summarized in Table 9.4B. The costs are discounted at 6 percent.

Table 9.4B Total Costs of Plan A4

Plan	STP Expansion at Current Treatment Level ($)	Additional Treatment ($)	Water Supply ($)	Reservoirs	Flood Protection Measures	Total ($)	Total Without STP Expansion ($)
				Montrose ($)	Dyking & Channelization ($)		
A4 Option (i)	93.99	29.53	14.17	4.00 Purchase and disposal of Montrose lands in 2001	23.95	165.64	71.65
A4 Option (ii)	93.99	29.53	14.17	15.31 Construction of reservoir in 2001	23.95	176.95	82.96

9.2 Plan B — Montrose Reservoir, Advanced Sewage Treatment, Local Sources of Water Supply

Plans B1 and B2 include the multi-purpose Montrose dam, having a total storage volume of about 77.7 million cubic metres (63,000 acre-ft) and, at some point in the future, advanced sewage treatment at Kitchener, Waterloo and Guelph. The future water supply components are the same as those incorporated in plan A1. Plan B2, with flood storage provided by the Montrose reservoir with dyking and channelization at the six major flood centres, provides additional flood damage reduction over plan A (Fig. 9.2).

Flood Damage Reduction

Plan B1 provides protection against a flood having a return period of 10 years at Cambridge and Brantford. Plan B2 provides protection for a flood having a return period greater than one hundred years. The difference in cost between the two plans is approximately $21 million (Table 9.5).

Water Quality Requirements

Plan B utilizes flow augmentation from the Montrose reservoir and advanced sewage treatment in Kitchener in the year 2001 and in Waterloo in the year 2021 to improve dissolved oxygen levels. It also minimizes the toxic effects of un-ionized ammonia in the central Grand river. Because the low flow augmentation benefits of the Montrose reservoir do not have any effects on the Speed river basin, possible future waste treatment requirements for Guelph are the same as those outlined for plan A. The costs and staging of both current and additional treatment as proposed in plan B are shown in Table 9.6.

Water Supply Requirements

As the water supply components of plan B are the same as indicated for plan A1, staging, new sources of supply, and costs are the same as in plan A1.

Table 9.5 Costs for Flood Protection Measures Included in Plan B

(Present Value of Costs in Millions of 1979 Dollars at 6% Discount)

	Flood Damage Centre	Flood Protection Measures By Plan B	Date Req'd	Cost* of Measures ($)
B1	Cambridge (Galt) Cambridge (Preston) Paris Brantford Caledonia Dunnville	Montrose Dam	1981	42.4**
	New Hamburg	Dykes	1981	0.8
	Total			43.2
B2	Cambridge (Galt)	Montrose Dam and Dykes and Channelization as in Plan A	1981	8.50
	Cambridge (Preston)			0.90
	Paris			5.30
	Brantford			6.40 + 42.4**
	Caledonia			0.85
	Dunnville			1.20
	New Hamburg	Dykes	1981	0.80
	Total			66.35

* Costs for Montrose dam are primarily capital costs; O&M costs are less than 1% of capital costs.

** Total cost of construction of the Montrose reservoir. Approximately one third of the cost can be allocated towards flood control and two thirds of the cost can be allocated towards flow augmentation for water quality improvement.

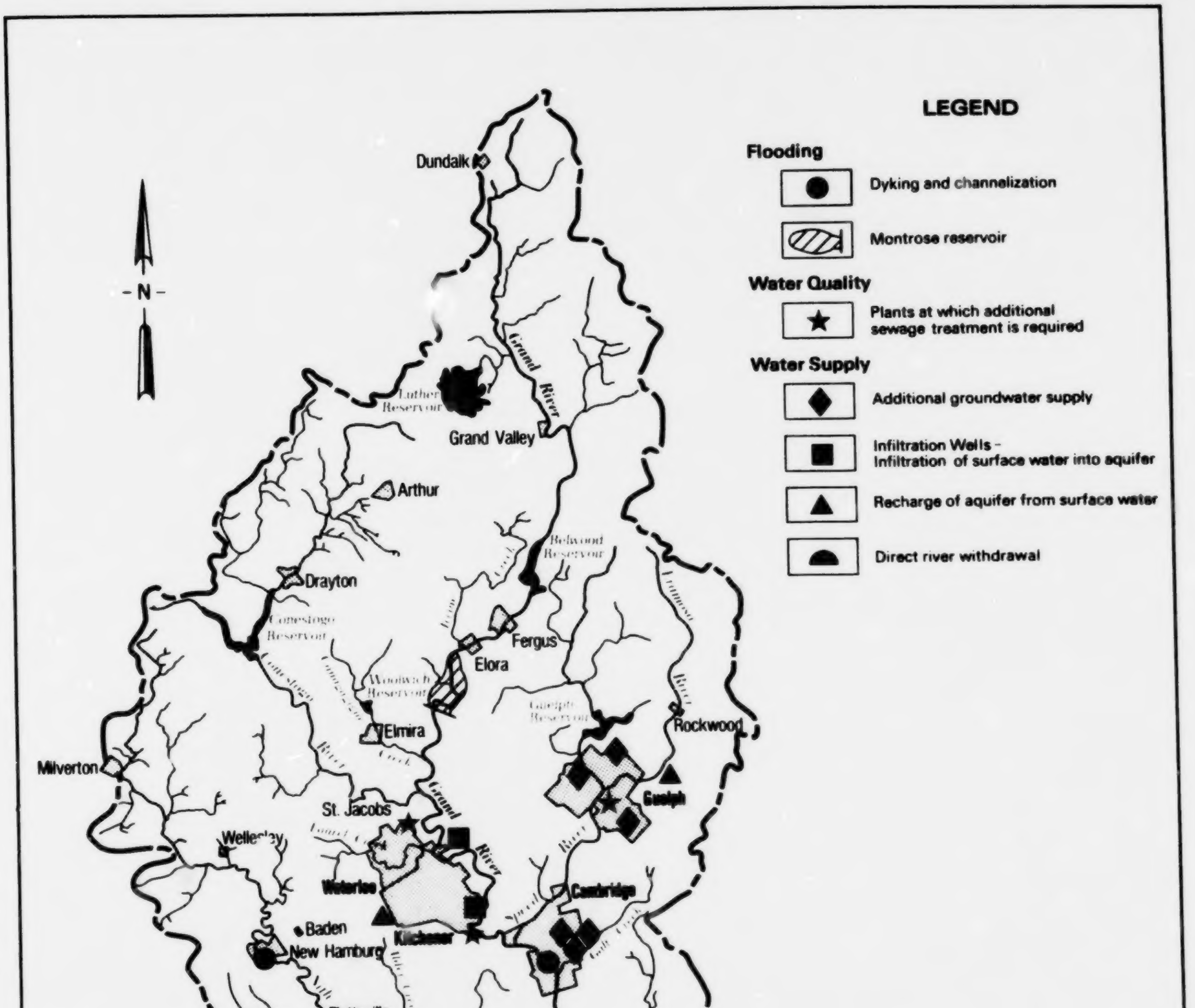

LEGEND
Flooding
●
Dyking and channelization
▨
Montrose reservoir
Water Quality
★
Plants at which additional sewage treatment is required
Water Supply
◆
Additional groundwater supply
■
Infiltration Wells - Infiltration of surface water into aquifer
▲
Recharge of aquifer from surface water
◓
Direct river withdrawal
N
Dundalk
Luther Reservoir
Grand River
Grand Valley
Arthur
Belwood Reservoir
Drayton
Conestogo Reservoir
Fergus
Elora
Woolwich Reservoir
Guelph Reservoir
Rockwood
Elmira
Milverton
St. Jacobs
Guelph
Wellesley
Waterloo
Cambridge
Baden
New Hamburg
Kitchener
Plattsville
Ayr
Bright
Drumbo
Paris
Princeton
Brantford
Caledonia
Hagersville
Cayuga
Dunnville
LAKE ERIE
0 5 10 20 30 Kilometres

Figure 9.2. Water Management Plan B2.

Table 9.6 Municipal Sewage Treatment Requirements for Plan B
(Present Value of Costs in Millions of 1979 Dollars at 6% Discount)

	Current Treatment				Additional Treatment Required				Total Costs		
		Expansion		Total O&M Costs ($)			Costs				
Municipality	Type	Date	Capital Costs ($)		Type	Date Req'd	Capital ($)	O&M ($)	Capital ($)	O&M ($)	Total ($)
Waterloo	CAS-P	2001	2.46	10.38	Nitrification Filtration	2021	0.73	0.18	3.19	10.56	13.75
Kitchener	CAS-P	2021	0.93	18.61	Nitrification Filtration	2001	4.08	0.89	5.01	19.50	24.51
Guelph	RBC Filtration	1996	10.16	16.88	Chemical* Treatment & Multi-Media Filtration	1981	6.30	4.60	16.46	21.48	37.94
Hespeler	High Rate CAS-P	2020	0.33	2.84					0.33	2.84	3.17
Galt	CAS-P	2006	1.59	8.98					1.59	8.98	10.57
Preston	CAS-P	2022	0.09	4.33					0.09	4.33	4.42
Paris	Extended Aeration	1981		2.16						2.16	2.16
Brantford	CAS-P	2026	0.43	13.82					0.43	13.82	14.25
TOTAL			15.99	78.00			11.11	5.67	27.10	83.67	110.77

* The addition of chemical treatment and multi-media filtration is conditional on the effectiveness of new treatment facilities recently added at the Guelph sewage treatment plant.

Environmental Impacts

Environmental impacts of waste treatment, water supply facilities and dykes and channelization for plan B remain unchanged from plan A.

The key environmental impacts of the Montrose reservoir are as follows:

- the Montrose reservoir would require 1,214 ha (3,000 acres) to 1,820 ha (4,500 acres) of land depending upon the acquisition plan. Table 9.7 describes the amount of agricultural land that would be removed from production by the reservoir
- downstream of the reservoir approximately 324 ha (800 acres) of agricultural land would be flooded less frequently
- areas of Class 1 and 2 land for the production of red pine and hard maples at the site would be lost
- based on upstream water quality conditions and observation of other major reservoirs in the basin, some degradation of water quality conditions in the reservoir site could be expected to occur such as depressed dissolved oxygen concentrations in the bottom waters of the reservoir and algal blooms in the fall. However, flow augmentation from the reservoir would improve the water quality conditions in the central Grand river (Chapter 10)
- there are some uncommon associations of vegetation, unusual floral species, rare bird species and one mammal species in the area which would be lost because of inundation and a change in habitat. The complexity of the ecosystem will also be decreased as habitat diversity is reduced. No serious impacts on the existing flora and fauna would occur in the Elora gorge which extends 3.4 km (2 miles) south of Elora.

EAST SIDE: Middle portion of the reservoir

WEST SIDE: Upstream of dam site

MONTROSE RESERVOIR SITE

Table 9.7 Lands Affected By the Montrose Reservoir (Multi-Purpose)

Agricultural Capability	Flooded Area (ha)	Minimum Acquisition Area (ha)	Maximum Acquisition Area (ha)
Class 1	168	412	801
Class 2	89	225	382
Class 3	136	266	291
Other	253	311	346
Total Area Affected	646	1214	1820
Total Area Presently Used For Agriculture	272	777	1275

Social Impacts

Social impacts of waste treatment and water supply requirements are the same as plan A.

The key social impacts of the Montrose reservoir are as follows:

- about 40 percent of the flooded area and 70 percent of the maximum acquisition area are actively farmed and would be affected directly or indirectly. Approximately twenty-four farms would be partially flooded, five farms would be totally inundated and seven farms would be seriously severed
- the Montrose reservoir levels would increase normal river levels in the lower downstream portion of the Elora gorge. The length of the gorge affected would vary from one-half to one-quarter, depending on the time of year. Since reservoir levels would affect only the lower downstream portion of the gorge, the views from the main sight-seeing vantage points would be unaffected. Most hiking trails would be unaffected
- presently, the recreational activities of the valley in the vicinity of West Montrose are unorganized pursuits. This pattern would be replaced by more intensive recreational uses similar to those of the existing reservoirs in the basin. The visual aesthetics would also be changed from a view of gently rolling landscapes adjacent to steep, heavily wooded valley slopes and a terraced floodplain which offers vividness and variety to a more uniform lake-like setting when the reservoir is full. In the fall, unsightly mudflats would be exposed in the drawdown zone
- the following number of residences would have to be relocated or purchased as a result of dam construction:

Flooded Area	17 homes
Minimum Acquisition Area	51 homes
Maximum Acquisition Area	69 homes

- a cultural facility, the Estonian Cultural Centre, would have to be relocated as well as five historic homes
- two roads with bridges crossing the Grand river would be closed while the county road through the hamlet of Inverhaugh would require improvements
- the community ties in the area may be disrupted due to a potential influx of tourists with associated noise and traffic; disruption of transportation patterns; and a change in community infrastructure (Ref. Tech. Report No. 32).

Total Costs of Plan B — Montrose Reservoir

The capital and operation-maintenance costs for plans B1 and B2 are summarized in Table 9.7A. Costs are in millions of 1979 dollars and are discounted at 6 percent.

Table 9.7A Total Costs of Plans B1 and B2

Plan	STP Expansion at Current Treatment Level ($)	Additional Treatment ($)	Water Supply ($)	Reservoirs	Flood Protection Measures	Total ($)	Total Without STP Expansion ($)
				Montrose Dam	Dyking & Channelization		
B1	93.99	16.78	14.17	42.40	0.80	168.14	74.15
B2	93.99	16.78	14.17	42.40	23.95	191.29	97.30

9.3 Plan C — Single-Purpose Reservoir for Flood Control, Advanced Sewage Treatment, Local Sources of Water Supply

Each one of the plan options C1, C2 and C3 includes a single-purpose flood control reservoir designed solely to reduce flood damages (Fig. 9.3). Plan C1 uses the St. Jacobs reservoir with a storage volume of 6.3 million cubic metres (13,250 acre-ft), located on the Conestogo river to reduce flood damages. Plan C2 considers the effect of a small Montrose reservoir having a storage volume of 24.7 million cubic metres (20,000 acre-ft). Plan C3 utilizes a Montrose reservoir with the same total storage volume as in plan B (77.7 million cubic metres (63,000 acre-ft)). In each of the C plans, the reservoir would be used strictly for reducing flood damages rather than using part of the storage for other uses such as low flow augmentation as was done in plan B2. The single-purpose or dry reservoir option is an alternative to dyking and channelization of the major urban areas.

The sewage treatment and water supply components for all three C options are the same as for plan A1. The plan C options differ from plan A1 only in their manner of reducing flood damages.

Flood Damage Reduction

Each plan C reservoir option would be operated in the following manner. The reservoir would only be filled during flood periods, and it would be emptied as soon as flood flows subside. The remainder of the time the reservoir would remain empty or dry. It is estimated that the reservoir lands would only be flooded, on the average, one or two times a year. If the reservoir was flooded dur-

Table 9.8 Costs for Flood Protection Measures Included in Plan C

(Present Value of Costs in Millions of 1979 Dollars at 6% Discount)

	Flood Damage Centres	Flood Protection Measures By Plan C	Date Req'd	Cost of Measures ($)
C1	Cambridge (Galt) Cambridge (Preston) Paris Brantford Caledonia Dunnville	St. Jacobs Dry Reservoir 16.3 million cubic metres (13,250 Acre-Feet)	1981	25.0
	New Hamburg	— Dykes	1981	0.8
	Total			25.8
C2	Cambridge (Galt) Cambridge (Preston) Paris Brantford Caledonia Dunnville	Small Montrose Dry Reservoir 24.7 million cubic metres (20,000 Acre-Feet)	1981	28.1
	New Hamburg	— Dykes	1981	0.8
	Total			28.9
C3	Cambridge (Galt) Cambridge (Preston) Paris Brantford Caledonia Dunnville	Large Montrose Dry Reservoir 77.7 million cubic metres (63,000 Acre-Feet)	1981	42.4
	New Hamburg	— Dykes	1981	0.8
	Total			43.2

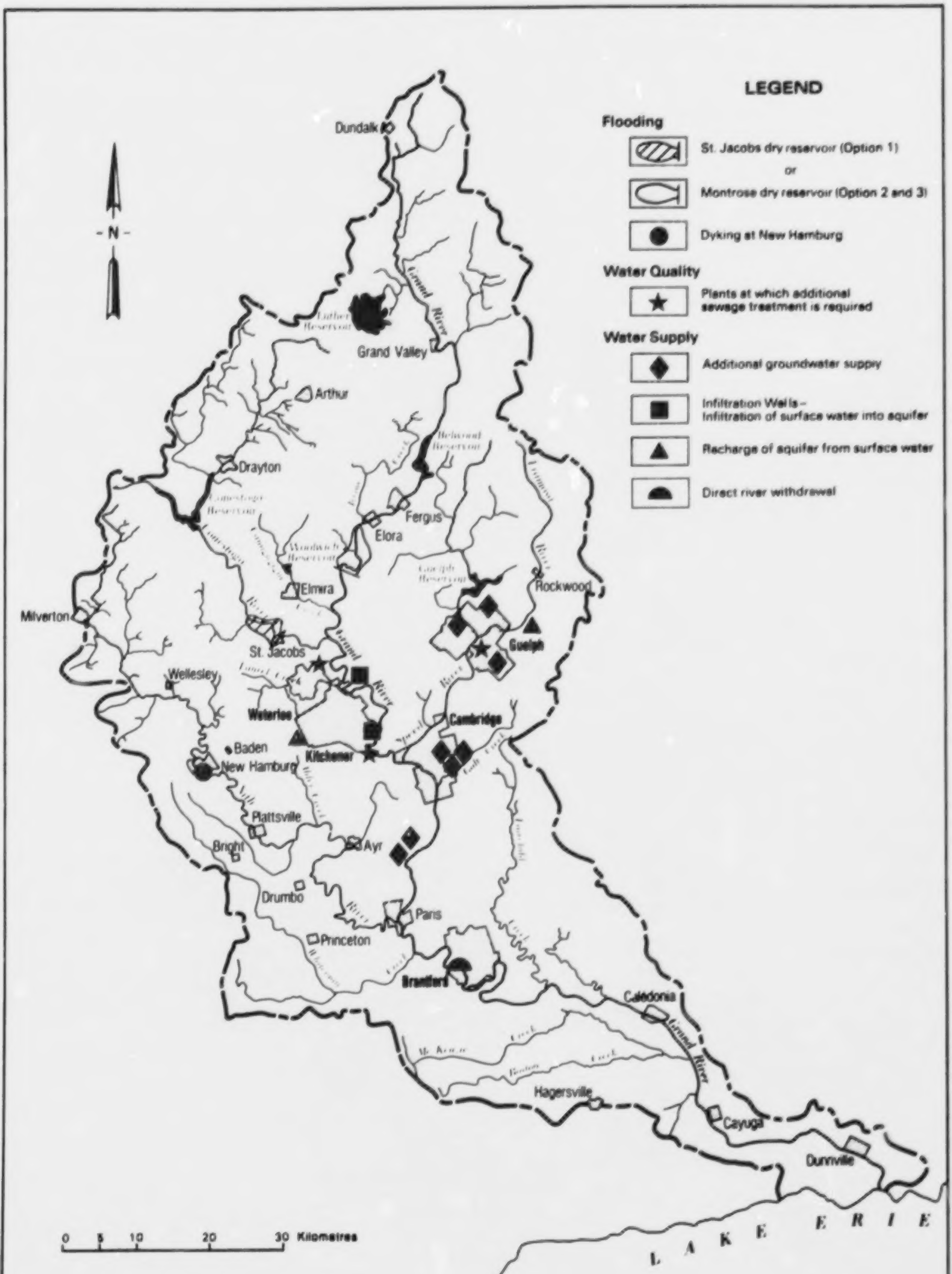

LEGEND
Flooding
St. Jacobs dry reservoir (Option 1)
or
Montrose dry reservoir (Option 2 and 3)
Dyking at New Hamburg
Water Quality
Plants at which additional sewage treatment is required
Water Supply
Additional groundwater supply
Infiltration Wells – Infiltration of surface water into aquifer
Recharge of aquifer from surface water
Direct river withdrawal
N
Dundalk
Luther Reservoir
Grand River
Grand Valley
Arthur
Belwood Reservoir
Drayton
Conestogo Reservoir
Fergus
Elora
Woolwich Reservoir
Elmira
Guelph Reservoir
Rockwood
Eramosa River
Milverton
St. Jacobs
Guelph
Wellesley
Waterloo
Cambridge
Baden
New Hamburg
Kitchener
Nith River
Plattsville
Ayr
Bright
Drumbo
Paris
Princeton
Brantford
Caledonia
Hagersville
Cayuga
Dunnville
LAKE ERIE
0 5 10 20 30 Kilometres

Figure 9.3. Water Management Plan C.

Table 9.9 Lands Affected by St. Jacobs Single-Purpose Dam and Reservoir
(Figures in parentheses refer to hectares presently in crops)

Agricultural Capability	Flooded Area (ha)	Minimum Acquisition Area (ha)
Class 1 to 3	164	330
Other Lands	164	318
Total Area Affected	328 (122)	648 (337)

ing the spring freshet, the drawdown period may last longer than one week. However, if flooding occurred during the summer months, the reservoir could be emptied in three to five days.

The flood damage reduction and the amount of storage provided for a given level of flood damage reduction for each option in plan C is shown on Table 9.8.

Environmental Impacts

The environmental impacts of the construction of waste treatment and water supply facilities of plan C are the same as those described for plan A.

In general, the environmental impact of a dry, single-purpose reservoir would not be as great as that of a multi-purpose reservoir, since reservoir lands would only be flooded periodically for a short time. The potential of the land for agriculture and forestry purposes at the reservoir site may be decreased due to the increased flooding potential. Terrestrial flora and fauna may be affected temporarily, mainly during construction and spring flooding. Adverse impacts to aquatic flora and fauna would be minimal.

C1 — St. Jacobs site

Within the 648 ha (1,600 acres) acquisition area of the St. Jacobs reservoir, 337 ha (832 acres) are currently being used for cropland. If the dam was constructed, lands now in production within the acquisition area could continue to be used for agriculture including 121.5 ha (300 acres) in the flooded zone that could be used as pasture land (Table 9.9).

The habitats of three rare flora species are found at the St. Jacobs site and may be partially destroyed by increased flooding. These species are the white trout lily, harbinger of spring, and twinleaf.

C2 — Montrose-small site

Within the acquisition areas of the Montrose reservoir, 510 ha (1,260 acres) are presently used for cropland. Three hundred and eleven ha (770 acres) could be retained for agricultural use in the acquisition area, with a further 199 ha (490 acres) in the flood zone reserved for pasture (Table 9.10).

The habitats of the twinleaf and white trout lily which are found near the dam site may be damaged or lost by increased moisture at the site. Elora gorge flora would not be affected. Fauna at the site could be temporarily disrupted with seasonal flooding of the site. Fish should not be affected. However, there is a possibility that some may be stranded on land when the reservoir is emptied.

C3 — Montrose-large site

Environmental effects are similar to those of the Montrose-small site except for the land area affected which is the same as the reservoir areas listed in Table 9.7.

Table 9.10 Lands Affected by the Montrose Single-Purpose Dam and Reservoir
(Figures in parentheses refer to hectares presently in crops)

Agricultural Capability	Flooded Area (ha)	Minimum Acquisition Area (ha)
Class 1 to 3	296	713
Other Lands	199	239
Total Area Affected	495 (199)	952 (510)

Social Impacts

The social impacts of waste treatment and water supply requirements for any single-purpose reservoir option are the same as those outlined for plan A.

C1 — St. Jacobs site

The major social effect of St. Jacobs dam is the disruption of established communities in the area as a result of relocating four homes in the flooded zone and about twenty homes in the minimum acquisition area. Sixteen farm units in these areas would also be affected to varying degrees. Temporary disruption of transportation corridors during construction and flooding would cause some inconvenience. The strong Mennonite community ties which now exist may be weakened. If a dam is built, the bridge which connects the communities to either side of the river should be raised. One historical home in the flooded area would be removed.

C2 — Montrose-small site

Many of the social impacts resulting from plan B2 would be incurred with plan C2. Although the hamlet of Inverhaugh would be outside of the acquisition zone, the Estonian Cultural Centre would be entirely within the acquisition zone. Fifteen homes in the flooded and acquisition areas would have to be permanently relocated by the small single-purpose reservoir option at Montrose. Downstream of the Montrose reservoir, approximately 324 ha (800 acres) of agricultural land would benefit from reduced flood damages.

Transportation patterns would be affected since two roads with bridges crossing the Grand river would be closed, while the county road through Inverhaugh would require some improvements.

C3 — Montrose-large site

Social effects include all those which apply to the Montrose-small site, and in addition, sixty-eight homes would be affected in the minimum acquisition area.

Total Costs of Plans C1, C2 and C3 — Single-Purpose Dam Options

The capital and operation-maintenance costs are summaried in Table 9.10A. Costs are in millions of 1979 dollars and are discounted at 6 percent.

Table 9.10A Total Costs of Plans C1, C2 and C3

Plan	STP Expansion at Current Treatment Level ($)	Additional Treatment ($)	Water Supply ($)	Flood Protection Measures		Total ($)	Total Without STP Expansion ($)
				Dry Dam	Dyking & Channelization		
C1 St. Jacobs Dry Reservoir	93.99	29.53	14.17	25.0	0.80	163.49	69.50
C2 Small Montrose Dry Reservoir	93.99	29.53	14.17	28.1	0.80	166.59	72.60
C3 Large Montrose Dry Reservoir	93.99	29.53	14.17	42.4	0.80	180.89	86.90

9.4 Plan D — Lake Erie Water Supply Pipeline, Advanced Sewage Treatment, Dykes and Channelization

Plan D replaces several of the local ground water and river supplies of plans A, B, and C with a Lake Erie source of supply. A pipeline from Lake Erie would supply water to Brantford, Cambridge, Kitchener and Waterloo. Except for water supply, all other aspects of the plan are similar to plan A. The features of plan D are illustrated in Figure 9.4.

Water Supply Requirements

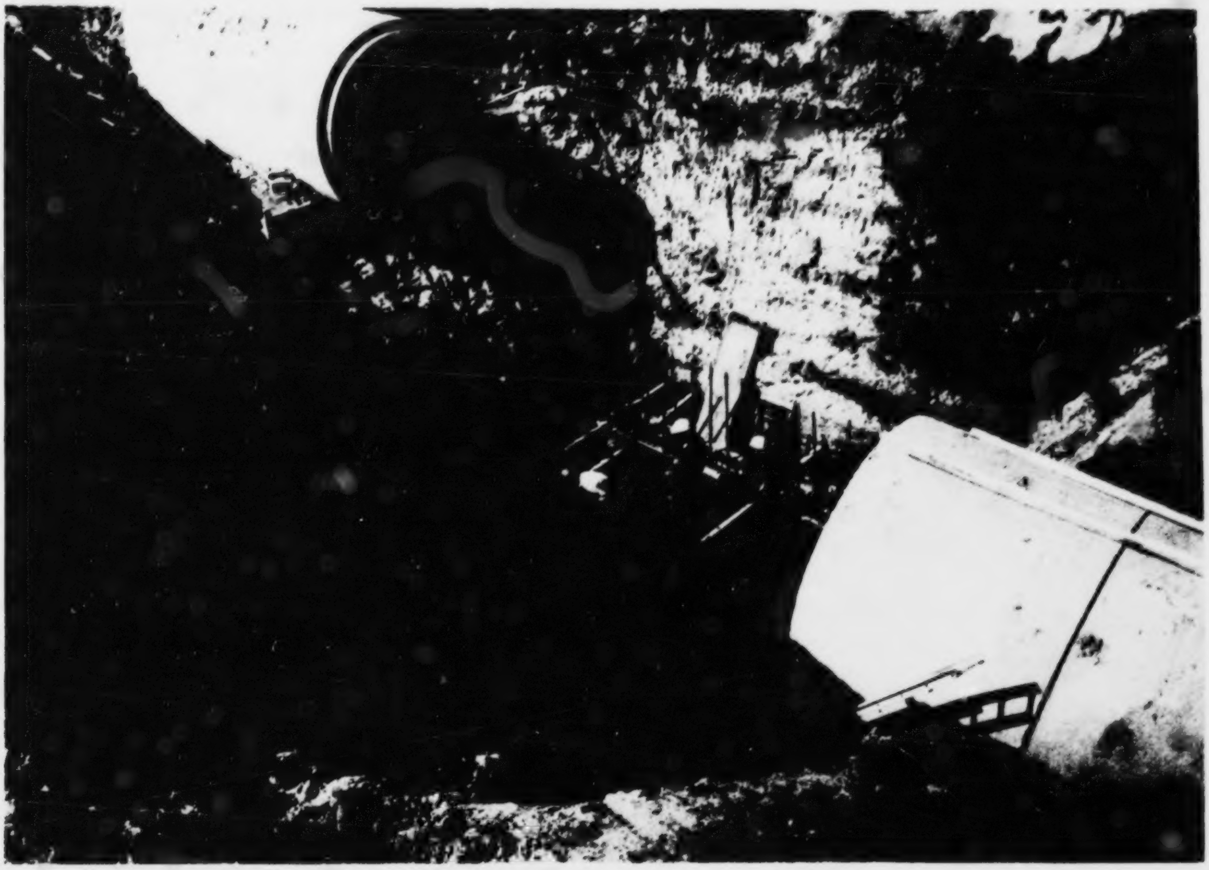
In the past, Lake Erie, Lake Ontario, Lake Huron and Georgian Bay have been studied as possible sources for a water supply pipeline to the Kitchener-Waterloo area. Water quality in each of these lakes is acceptable for municipal water supply purposes and was not a major factor in selecting a particular pipeline scheme. Physical conditions of the pipeline route, and construction and operation costs were the most important factors in making a decision. Lake Erie was the most economical of all the choices and was the pipeline route selected by the basin study for further appraisal. The costs of the pipeline and Guelph water supply in plan D are shown on Table 9.11.

Water Quality Requirements

The sewage treatment requirements of plan D are the same as in plan A. Under plan D, the cost of water will be higher than the water supply costs of plan A, B or C and demand will be reduced accordingly. This reduction in consumption may reduce the needed size of the sewage treatment plants, postponing the need for new expansions by about 5 years or more (Table 9.12). Total municipal sewage treatment costs are $5 million less than plan A.

Flood Damage Reduction

Reductions in flood damage are carried out by the same dyking and channelization system as described in plan A.



A WATER SUPPLY PIPELINE: Construction of the Lake Huron to London water supply pipeline. Excavation and pipe sizes would be similar for a Lake Erie to Kitchener-Waterloo pipeline

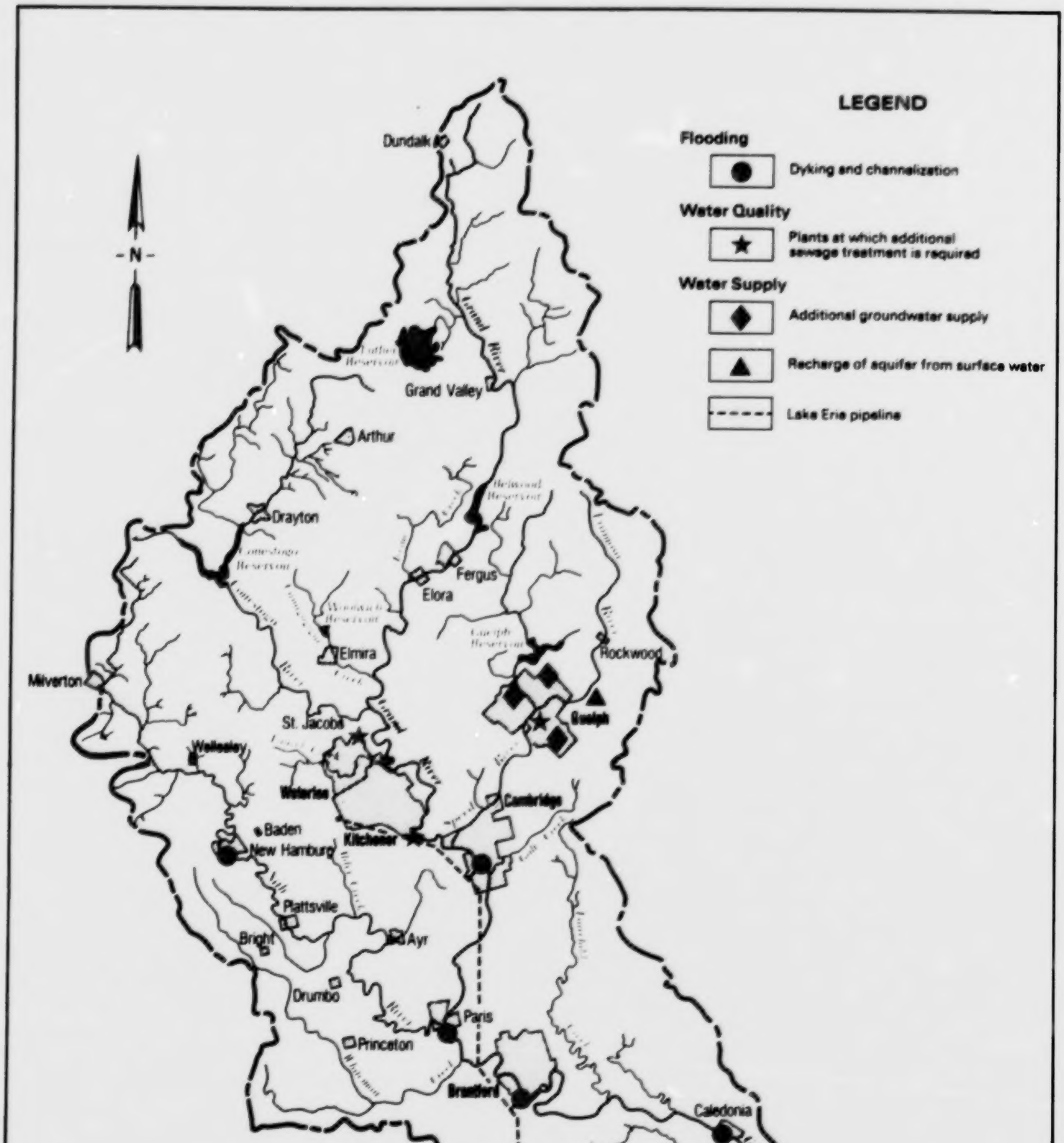

LEGEND
Flooding
● Dyking and channelization
Water Quality
★ Plants at which additional sewage treatment is required
Water Supply
◆ Additional groundwater supply
▲ Recharge of aquifer from surface water
- - - - Lake Erie pipeline
N
Dundalk
Luther Reservoir
Grand River
Grand Valley
Arthur
Belwood Reservoir
Drayton
Conestogo Reservoir
Fergus
Elora
Woolwich Reservoir
Elmira
Guelph Reservoir
Rockwood
Milverton
St. Jacobs
Guelph
Wellesley
Waterloo
Cambridge
Speed River
Baden
New Hamburg
Kitchener
Nith River
Plattsville
Bright
Ayr
Drumbo
Paris
Princeton
Brantford
Caledonia
Hagersville
Cayuga
Dunnville
0 5 10 20 30 Kilometres
LAKE ERIE

Figure 9.4. Water Management Plan D.

Table 9.11 Water Supply Requirements and Costs for Plan D
(Present Value of Costs in Millions of 1979 Dollars at 6% Discount)

Municipality	Current Source of Water Supply	Date When Additional Capacity is Required	Source of New Supply	Capital ($)	O&M ($)
Kitchener Waterloo	Ground Water and Induced Infiltration	1981	Lake Erie Water Supply Pipeline	194.00	83.70
Cambridge	Ground Water				
Brantford	River Water				
Guelph	Ground Water and Arkell Recharge	2011	New Ground Water	0.09	0.02
		2021	Expanded Arkell Recharge	0.02	0.01
Total				194.11	83.73

Table 9.12 Municipal Sewage Treatment Requirements for Plan D
(Present Value of Costs in Millions of 1979 Dollars at 6% Discount)

	Current Treatment				Additional Treatment Required				Total Costs		
		Expansion					Costs				
Municipality	Type	Date	Capital Costs ($)	Total O&M Costs ($)	Type	Date Req'd	Capital ($)	O&M ($)	Capital ($)	O&M Costs ($)	Total Costs ($)
Waterloo	CAS-P	2006	1.73	9.92	Nitrification Filtration	2001	1.85	0.90	3.58	10.82	14.40
Kitchener	CAS-P	2031	0.33	18.06	Nitrification Filtration	1981	12.44	2.90	12.77	20.96	33.73
Guelph	RBC Filtration	1996	10.16	16.88	Chemical* Treatment & Multi-Media Filtration	1981	6.34	4.63	16.50	21.51	38.01
Hespeler	High Rate CAS-P	2031		2.75						2.75	2.75
Galt	CAS-P	2011	1.10	8.60					1.10	8.60	9.70
Preston	CAS-P	2022		4.17						4.17	4.17
Paris	Extended Aeration	1981		2.16						2.16	2.16
Brantford	CAS-P	2031		13.15						13.15	13.15
TOTAL			13.32	75.69			20.63	8.43	33.95	84.12	118.07

* The addition of chemical treatment and multi-media filtration is conditional on the effectiveness of new treatment facilities recently added at the Guelph sewage treatment plant.

Environmental Impacts

Environmental impacts of sewage treatment facilities, dykes and channelization are the same as in plan A.

Environmental impacts of the proposed Lake Erie pipeline largely occur during construction and include: interference with waterfowl habitat by draining or filling marshy areas; disturbance to aquatic life by crossing streams, small lakes and swamps; disturbance to plant and animal life within the construction corridor; decrease in timber production by removing forested areas. With careful planning to avoid sensitive areas and skilled and well supervised construction practices, most of the detrimental environmental impacts can be avoided or effectively mitigated.

Social Impacts

The social impacts of sewage treatment facilities, dykes and channelization are the same as in plan A.

The social impacts associated directly with the pipeline construction occur mainly along the pipeline route and may include temporary disruption of transportation corridors and agricultural production during construction; decreased land productivity during rehabilitation, vegetative clearing of the right-of-way; and temporary inconvenience to residents living adjacent to the pipeline right-of-way. Positive social impacts include the lifting of possible constraints on water use at peak time and the provision of an incentive for industries to locate in the basin. However, along the pipeline route as a result of an abundant piped water supply, indirect changes may arise such as increased development with resultant changes in population and land uses.

Total Costs of Plan D — Lake Erie Water Supply Pipeline, Advanced Sewage Treatment, Dykes and Channelization

The capital and operation-maintenance costs for plan D are summarized in Table 9.12A. Costs are in millions of 1979 dollars and are discounted at 6 percent. This plan has the highest annual operation and maintenance costs of the four plans (over $5 million per annum). This is largely due to the high cost of pumping water from Lake Erie to the Regional Municipality of Waterloo.

Table 9.12A Total Costs of Plan D

Plan	STP Expansion at Current Treatment Level ($)	Additional Treatment ($)	Water Supply ($)	Flood Protection Measures	Total ($)	Total Without STP Expansions ($)
				Dyking & Channelization		
D	89.01	29.06	277.84	23.95	419.86	330.85

9.5 Reservoir Low Flow Operation

Grand River

At present, the existing reservoir system (Chapter 6) provides summer river flow augmentation in order to maintain water quality in the central Grand river and to provide an adequate source of water supply to Brantford and Cayuga.

Future additional water demands for the Cities of Kitchener and Waterloo can be met through the recharge of the Mannheim aquifer by surface water abstracted from the Grand river. Adequate surface flow can be ensured by appropriate reservoir operations.

The existing reservoir system can supply the recharge system for existing and future water demands provided that the winter operation of Belwood reservoir is changed (Sec. 10.5.2). More winter flow regulation is required than is carried out at present (Ref. Tech. Report No. 38).

Table 9.13 examines the reliability of several different low flow reservoir operation policies for the main plans. Plans A, C and D use the existing reservoir system for flow augmentation and plan B uses the existing reservoir system plus the Montrose reservoir to augment flows.

At present, the reservoirs are regulated during the summer months, May to October, to keep the river flow from falling below 11.3 m^3/s (400 cfs) at Doon and 17 m^3/s (600 cfs) at Brantford. The number of times these targets or objectives are met or exceeded is measured by a reliability index. Reliability is based upon either the number of years (occurrences) the targets are achieved 100 percent of the time or the amount of time the objectives or targets are met or exceeded within the operating period. Both indexes are given in Tables 9.13 and 9.14.

Option 1 for plans A, C and D represents the existing summer operation policy. This policy provides the least reliable regulated flow and the minimum flow during periods when the target is not achieved.

By decreasing the summer target flow at Doon by 1.4 m^3/s (50 cfs) to 9.9 m^3/s (350 cfs) and leaving the Brantford target unchanged, option 2 for plans A, C and D provides a more reliable summer regulated flow at Doon and Brantford. Option 2 also increases the minimum summer daily flow at Doon by up to 1.8 m^3/s (62 cfs)

Table 9.13 Reliability of Meeting Minimum Flow Targets at Kitchener (Doon) and Brantford

Plan	Operating Policy Options		Grand River Minimum Summer (May 1 to Oct 31) Targets At		Grand River Minimum Winter Targets At (Nov 1 to Dec 31)		(Jan 1 to Apr 30)	
			Doon (m^3/s)	Brantford (m^3/s)	Doon (m^3/s)	Brantford (m^3/s)	Doon[4] (m^3/s)	Brantford[4] (m^3/s)
A C D	1 Existing Summer Policy	Minimum Target Flow	11.3	17.0	7.1	–	2.8	
		Reliability (occurrence)	58.8%	64.7%	64.7%		100%	
		Reliability (time)	94.6%	98.0%	86.5%		100%	
		Actual Minimum Weekly Flow	7.1	14.6	5.0	10.1	3.9	7.2
		Actual Minimum Daily Flow	6.5 (Oct)	14.2 (Oct)	4.6	9.5	3.7	6.6
A C D	2	Minimum Target Flow	9.9	17.0	7.1	–	2.8	
		Reliability (occurrence)	82.4%	88.2%	88.2%		100%	
		Reliability (time)	98.9%	99.6%	94.5%		100%	
		Actual Minimum Weekly Flow	8.5	14.8	5.5	10.7	3.9	7.3
		Actual Minimum Daily Flow	8.3 (Oct)	14.4 (Oct)	5.1	9.7	3.8	6.7
A C D	3	Minimum Target Flow	9.9	14.2	7.1	–	2.8	
		Reliability (occurrence)	100%	100%	100%		100%	
		Reliability (time)	100%	100%	100%		100%	
		Actual Minimum Weekly Flow	9.9	14.2	7.1	11.6	4.2	7.6
		Actual Minimum Daily Flow	9.9	14.2	7.1	10.8	4.1	7.1
B	1	Minimum Target Flow	12.7	17.0	8.5	8.5	4.2	–
		Reliability (occurrence)	88.2%	100%	82.4%	–	100%	–
		Reliability (time)	98.8%	100%	96.2%	–	100%	–
		Actual Minimum Weekly Flow	10.3	17.0	7.9	15.9	6.7	10.0
		Actual Minimum Daily Flow	9.9 (Oct)	17.0	7.2	11.7	5.5	9.5
B	2	Minimum Target Flow	12.7	19.8	8.5	–	4.2	–
		Reliability (occurrence)	70.6%	76.5%	76.5%	–	100%	
		Reliability (time)	95.7%	98.1%	90.2%	–	100%	–
		Actual Minimum Weekly Flow	10.2	17.1	7.2	11.8	5.8	10.0
		Actual Minimum Daily Flow	9.9 (Oct)	16.7 (Oct)	7.0	10.6	5.5	9.5

1) Because of the 30 hour travel time from the reservoirs to Doon, the daily flows can vary approximately ± 0.9 m^3/s from the target. The travel time from the reservoirs to Brantford is 48 hours. The daily flows can vary ± 1.4 m^3/s from the target.

2) Reliability (occurrence) refers to the percentage of days target was met in 17 years of flow record (glossary).

3) Reliability (time) refers to the percentage of days target was met within operating period for 17 years of flow record (glossary).

4) During November to December, flows can be measured at Doon and Brantford, but due to ice conditions during January to April, flows can not be accurately measured at these stations. Therefore, from January to April, equivalent target flows will be set at the outlet of Belwood reservoir where winter flows can be estimated (Ref. Tech. Report No. 38).

during periods when the target was not achieved. This option is the recommended reservoir regulation plan for the existing system.

By reducing the target at Brantford by 2.8 m^3/s (100 cfs) to 14.2 m^3/s (500 cfs) and leaving Doon unchanged at 9.9 m^3/s (350 cfs), option 3 provides the most reliable flow, meeting the target 100 percent of the time. However, any reduction in dilution at Brantford may result in some deterioration in water quality and increased water treatment costs.

The Montrose reservoir of plan B increases the summer target flows at Doon by 2.8 m^3/s (100 cfs) and the winter target flows by 1.4 m^3/s (50 cfs). Two options are considered: option 1, which leaves the summer target at Brantford unchanged at 17 m^3/s (600 cfs) and option 2, in which the summer Brantford target is increased to 19.6 m^3/s (700 cfs). However, this increase in the target results in less reliable summer regulated flows at Brantford and Doon.

Speed River

The Speed river flows are augmented during the summer by the Guelph reservoir in order to improve water quality conditions below the City of Guelph. The present reservoir regulation policy (Table 9.14) is to maintain a minimum of 1.1 m^3/s (40 cfs) at Guelph (Hanlon Expressway) from May to October. This can be achieved 100 percent of the time. A proposed revision to the present regulation policy, (option 2), is to increase the flow objective or target at Guelph to 1.7 m^3/s (60 cfs) during June to September. This policy can achieve the objective with a reliability of 80 percent on an occurrence basis and 93 percent on a time basis. The reliability is estimated assuming future operation of the mini-hydro generator at Guelph dam and abstraction of water from the Eramosa river by the City of Guelph for water supply purposes.

The addition of the Everton reservoir in plan A3 would increase the target by 1.1 m^3/s (40 cfs) to 2.8 m^3/s (100 cfs) for approximately the same reliability as option 2.

Table 9.14 Reliability of Meeting Minimum Flow Targets at Guelph on the Speed River (at Hanlon above Guelph STP)

Plan	Operating Policy Options		Speed River Minimum Summer Targets (m^3/s)			Speed River Minimum Winter Targets (m^3/s)	
			May	June-Sept.	October	Nov-Dec.	Jan-Apr.
All plans except Plan A3	1 Existing Summer Policy	Minimum Target Flow	1.1	1.1	1.1		
		Reliability (occurrence)[1]	100%	100%	100%	--	--
		Reliability (time)[2]	100%	100%	100%	--	--
		Actual Minimum Weekly Flow					
		Actual Minimum Daily Flow					
	2	Minimum Target Flow	1.1	1.7	1.1	1.1	1.1[3]
		Reliability (occurrence)[1]	100%	80%	86.7%		
		Reliability (time)[2]	100%	93%	95.5%		
		Actual Minimum Weekly Flow	1.7	1.5	1.0	1.1	1.2
		Actual Minimum Daily Flow	1.5	1.5	1.0	1.6	1.0
A3	1	Minimum Target Flow	1.7	2.8	1.7	1.1	1.1
		Reliability (occurrence)[1]					
		Reliability (time)[2]					
		Actual Minimum Weekly Flow					
		Actual Minimum Daily Flow					

1) Reliability (occurrence) refers to the percentage of years target was met in 7 years of flow records (glossary).

2) Reliability (time) refers to the percentage of days target was met within operating period for 17 years of flow records (glossary).

3) During November to December, flows can be measured at the Hanlon gauge on the Speed river, but due to ice conditions during January to April, flows can not be accurately measured during this time interval. Therefore, from January to April, equivalent target flows will be set at the outlet of the Guelph reservoir where winter flows can be estimated.

9.6 General Water Management Practices Supporting The Main Plans

This section describes water management practices which would enhance the effectiveness of all four main plans. These practices are largely non-structural and focus on the wise use of land and water resources from the water management perspective. In the following sections, general water management practices are discussed relative to the basin study objectives.

9.6.1 Practices To Reduce Flood Damage

Regulation of Floodplain Development

Potential flood damages may be minimized by prohibiting and/or restricting development on flood-prone lands. The existing mechanism for controlling floodplain development falls into two categories: provincial regulations administered by the Grand River Conservation Authority (GRCA); and official plans and zoning by-laws enacted and implemented by municipalities. Through co-operation and co-ordination, these tools are complimentary and can be effective in controlling construction in flood-prone areas.

The Grand River Conservation Authority has adopted a two-zone concept for regulating floodplain development. Floodplain lands are divided into two specific flood risk zones: the floodway and the flood fringe.

Development within the floodway is not permitted. Within the flood fringe, residential development in an urban location is permitted only if it is of an "infilling" nature and certain flood-proofing measures are carried out. In rural areas any proposed structures are subject to flood-proofing stipulations before a permit for construction is granted.

Several municipalities within the basin have enacted official plans which designate areas prone to flooding. In these areas, zoning by-laws prohibit development usually following as guidelines, the floodplain policies implemented by the Grand River Conservation Authority.

Flood Proofing

Flood-proofing measures entail design changes made to proposed and existing structures which reduce damage during flooding. These changes are primarily structural but they may also involve modification to uses and contents of structures. Landfilling, structural strengthening of buildings, permanent closing of openings in outer walls, equipping storm drains with flap valves to prevent backup of storm waters, installation of water-resistant wiring and reinforced windows and doors are examples of flood-proofing measures which can be undertaken.

At present, the Grand River Conservation Authority stipulates the incorporation of various flood-proofing measures as a prerequisite before issuing a permit to construct in the floodplain. Some flood proofing of existing structures has been completed by homeowners and businesses on an individual basis. A study of flooding on the Grand river found that 13 percent of the respondents to a questionnaire had modified their homes or businesses to reduce flood damage (Ref. 13).

Studies indicate that flood-proofing projects are worthy of implementation where:

1) large engineering works to control flooding are not feasible
2) a considerable time will occur before construction of large flood control projects
3) additional protection is needed in the event that flooding exceeds the design flood of the engineering works
4) some structural protection is required to supplement non-structural projects such as floodplain zoning
5) population density is too low to warrant large expensive projects (Ref. Tech. Report No. 32).

Flood proofing appears to be a viable alternative which could be carried out more extensively to reduce flood damages in the Grand river basin, although costs may be significant in flood proofing older buildings.

Flood Forecasting and Flood Warning

The Grand River Conservation Authority operates a flood forecasting and flood warning system which enables basin residents to move damageable items to a safe location and evacuate their premises if flooding is imminent.

The aim of the flood forecasting system is two-fold: to estimate river levels in order to most effectively operate reservoirs to reduce flood levels; and to provide as much information as possible to officials in the watershed as to the river levels that may be expected to occur. The information used in flood forecasting is based on a variety of sources including weather forecasts, weather data collection, snow surveys and river flow monitoring. A radio communications network operated by the Grand River Conservation Authority allows for uninterrupted monitoring of weather and river conditions.

In the case of imminent flooding, the Grand River Conservation Authority provides information regarding expected flood levels within the basin which is relayed through a fan-out system to various officials and the media. Municipalities are responsible for relaying flood warnings to the public and for taking emergency action such as evacuating floodplain residents and reinforcing dyking systems.

9.6.2 Practices to Improve Water Quality

Rural Non-Point Source Controls

Largely because of agricultural activities, the rural areas of the basin are the largest sources of sediment, nutrients and some heavy metals. Over 70 to 80 percent of this input occurs in the late winter or early spring during the spring runoff. Localized high levels of bacteria occur mainly in the summer from various agricultural activities. The present major sources of non-point pollution are in the basins of Canagagigue creek, Conestogo river, middle Grand river (West Montrose to Brantford), and the Nith river (Fig. 9.5). These areas represent the more intensively developed agricultural sub-basins of the watershed. The causes of non-point pollution and some applicable remedial measures are summarized for the subbasins in Table 9.15.

Recommended non-point source control measures are:

1) conservation tillage and no-tillage practices where applicable
2) stream bank stabilization
3) restriction of floodplain use to hay and pasture
4) restriction of cattle access to streams
5) establishment of buffer strips
6) land management practices which reduce soil erosion (winter cover crops, contour cropping, grassed waterways, etc.).

BUFFER STRIPS: A well-maintained municipal drain with an adequate buffer zone to reduce stream bank erosion and to trap sediments from adjacent fields

GRASSED WATERWAYS: Reduce erosion by allowing water to move across fields via a protected route

RESTRICTED CATTLE ACCESS: Unrestricted cattle access as shown on the left leads to increased stream bank erosion and increased nutrients during summer low flows. Cattle access can either be limited by ramps as shown on the right or by fencing

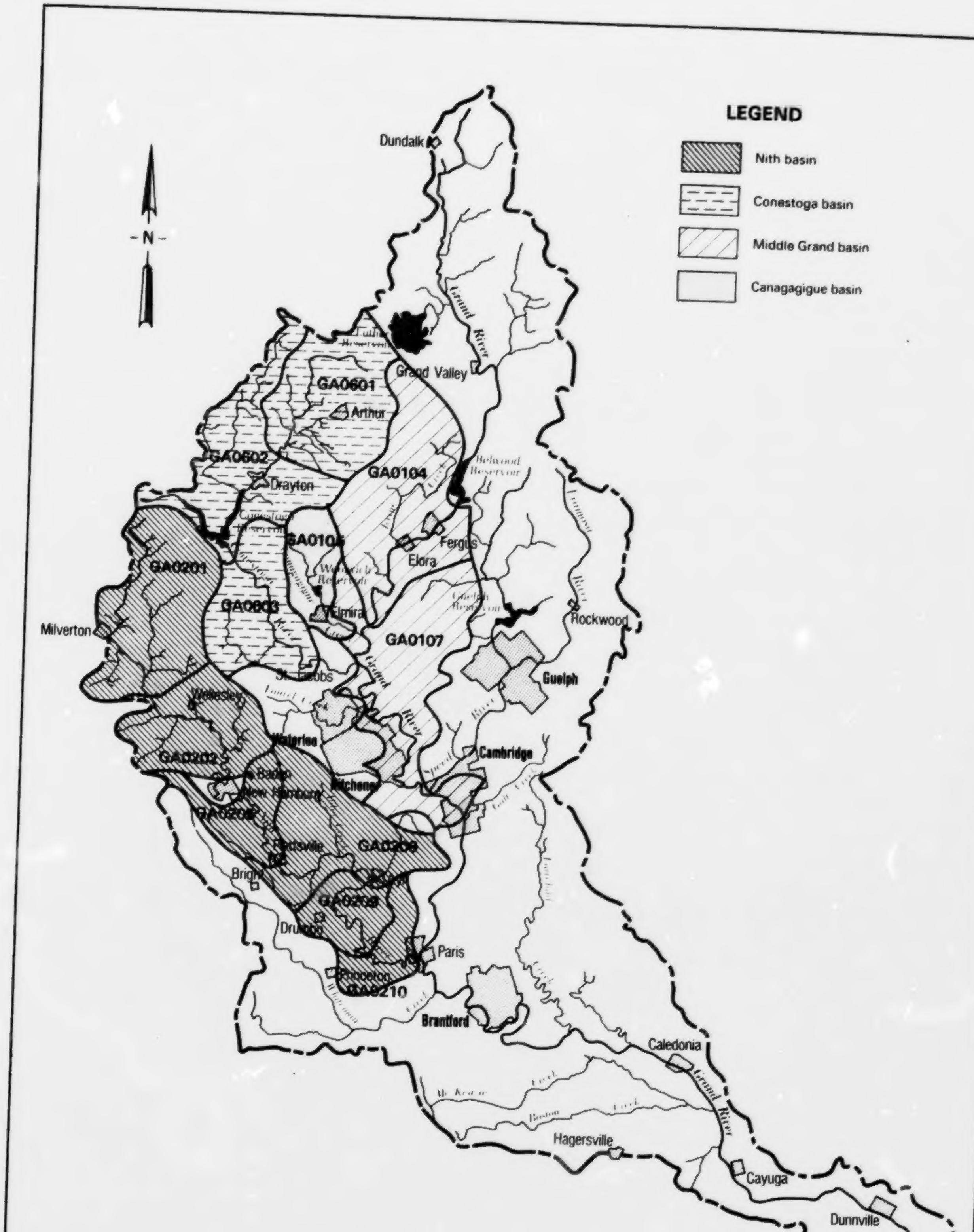
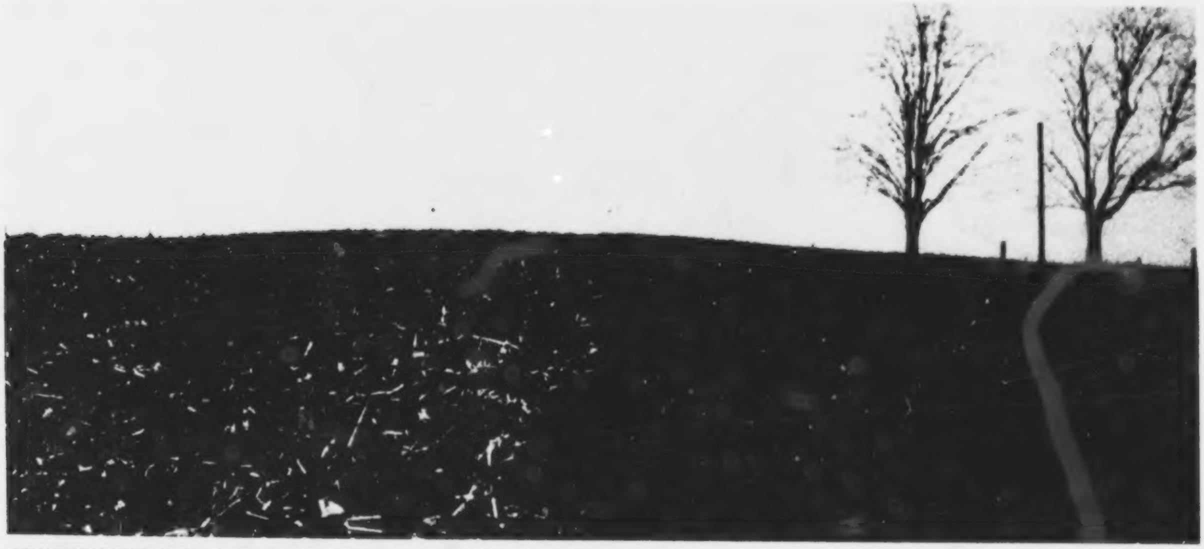

LEGEND
▨ Nith basin
Conestoga basin
Middle Grand basin
☐ Canagagigue basin
N
Dundalk
Grand River
Grand Valley
GA0601
Arthur
GA0602
Drayton
GA0104
Belwood Reservoir
Fergus
Elora
GA0106
Woolwich Reservoir
Elmira
GA0803
Conestogo Reservoir
GA0201
Milverton
GA0107
Guelph Reservoir
Rockwood
Guelph
St. Jacobs
Wellesley
Waterloo
Cambridge
GA0202
Baden
New Hamburg
Kitchener
GA0205
Plattsville
GA0208
Bright
GA0209
Drumbo
Paris
Princeton
GA0210
Brantford
Caledonia
Grand River
Hagersville
Cayuga
Dunnville
0 5 10 20 30 Kilometres
LAKE ERIE

Figure 9.5. Major sub-basins contributing to agricultural non-point source pollution.

Table 9.15 Major Causes of Agricultural Non-Point Source Pollution and Proposed Remedial Measures for Sub-basins with Intensive Agricultural Development in the Grand River Basin

Sub-basins	Major Causes of Non-Point Source Pollution	Remedial Measures
Middle Grand River		
1. Sub-basin GA0104	1. Stream bank erosion in Irvine Creek 2. Inadequate buffer strips	1. Stream bank stabilization 2. Widen buffer strips
2. Sub-basin GA0107	1. Stream bank erosion along Cox Creek 2. Cattle access to Hopewell Creek 3. Floodplain cultivation of crops along Hopewell Creek	1. Stream bank stabilization 2. Fencing to restrict cattle access to streams 3. Replace cultivation of row crops in the floodplain with hay crops and pasture
Canagagigue Creek		
1. Sub-basins GA0105 and GA0106	1. Stream bank erosion 2. Inadequate buffer strips 3. Probable cattle access to streams 4. Trout farm	1. Stream bank stabilization 2. Widen buffer strips 3. Fencing to restrict cattle access to streams
Conestogo River		
1. Sub-basin GA0601	1. Stream bank erosion 2. Inadequate buffer strips 3. Cattle access to streams	1. Stream bank stabilization 2. Widen buffer strips 3. Fencing to restrict cattle access to streams
2. Sub-basin GA0602	1. Stream bank erosion 2. Inadequate buffer strips 3. Cattle access to streams	1. Stream bank stabilization 2. Widen buffer strips 3. Fencing to restrict cattle access to streams
3. Sub-basin GA0603	1. Stream bank erosion 2. Inadequate buffer strips 3. Cattle access to stream	1. Stream bank stabilization 2. Widen buffer strips 3. Fencing to restrict cattle access to streams
Nith River		
1. Sub-basin GA0201	1. Stream bank erosion 2. Inadequate buffer strips 3. Cattle access to stream	1. Stream bank stabilization 2. Widen buffer strips 3. Fencing to restrict cattle access to streams
2. Sub-basin GA0202	1. Stream bank erosion 2. Inadequate buffer strips 3. Floodplain cultivation of crops	1. Stream bank stabilization 2. Widen buffer strips 3. Replace cultivation of row crops in the floodplain with hay crops and pasture
3. Sub-basins GA0205, GA0206, GA0209 and GA0210	1. Stream bank erosion 2. Inadequate buffer strips 3. Floodplain cultivation of crops	1. Stream bank stabilization 2. Widen buffer strips 3. Replace cultivation of row crops in the floodplain with hay crops and pasture



CONSERVATION TILLAGE: A field plowed conventionally (moldboard plow) on right is compared to a field plowed using a chisel plow on the left. This tillage practice leaves a large percent of residual vegetative material on or near the surface to serve as a protective mulch against the erosive actions of wind and water

Such control measures result in benefits to the farmer by savings in soil, fertilizer and time; and benefits to the river and lake by improvements in water quality. Rural non-point source controls will aid in reducing local water quality degradation and improve western Lake Erie water quality. Depending upon the effectiveness of the control measures in reducing nutrient inputs and thus controlling algal growth, the summer dissolved oxygen regime of the central Grand river may also be improved. A 50-75 percent reduction in nutrient input is required to make any noticeable improvement to the dissolved oxygen regime. The discounted costs of such measures and the related benefits are described in Table 9.16.

These cost estimates are approximate in nature and will require more detailed site surveys and evaluations. In addition, further research should be carried out to:

a) more accurately determine the effectiveness of each control measure in reducing sediment, nutrient and other pollutant loadings
b) determine the economic benefits resulting from incremental reductions in loadings
c) indicate the priority of control measures.

Less intensively developed agricultural portions of the basin are not presently contributing to existing water quality problems. However, if agricultural development should proceed according to an intensive development scenario, large increases in pollutant loads could occur (Sec. 3.2.2 and Ref. Tech. Report No. 27). Sub-basins where this could occur are the upper Grand river above West Montrose, Grand river below Brantford, Boston creek located just south of Caledonia, and Big creek located east of Brantford. In order to avoid the prospect of increased pollution from rural sources, the implementation of good agricultural practices will be required (Ref. Tech. Report No. 27).

Urban Non-Point Source Controls

Urban non-point pollution sources contribute to increased levels of sediment, nutrients, heavy metals, chlorides and bacteria in urban streams (Ref. Tech. Report No. 28). The bulk of these pollutants are washed off during the spring melt period (50-70%) and during intense rainstorms. Urban studies in the Grand river have indicated that major pollutants and their most probable sources of pollution are:

phosphorus — accumulation from dust fall, fecal matter from pets and wildlife, detergent from washing operations, decaying vegetation (leaves, grass clippings, etc.) and, (likely the largest source), fertilizer application
chloride — de-icing salt used on highways and streets for winter road maintenance
metals — dust and dirt accumulation on impervious surfaces from atmospheric sources, industrial activities and traffic (e.g. lead from automobile exhausts)
bacteria — from bird, rodent and pet feces, and catch basin sumps
sediments — erosion from construction sites and channel bed scour
— decaying vegetation
— dust and dirt accumulations on impervious surfaces (streets, roofs, parking lots, etc.)
pesticides — from residential and commercial lawn and garden insect and weed control.

Table 9.16 Costs and Benefits of Rural Non-Point Source Controls (Present Value of Costs in Millions of 1979 Dollars at 6% Discount)

Action	Costs (Million $)	Benefits to Farmers	Water Quality Benefit
Conservation tillage	varies	- labour, time, fertilizer, sustaining crop yields, retain topsoil	reduces sediment and nutrient loading
Stream Bank Stabilization	1.5	- reduces annual costs of ditches to farmer, reduces loss of adjacent farmland due to gullying, etc. protects tile outlets	reduces sediment loading and nutrient loading (5 to 30 percent)
Floodplain Management	3.6	- saving of topsoil	reduces sediment and nutrient loading (10 to 20 percent)
Restriction of cattle access to stream and ditches	0.3	- prevent destruction of banks, reduces cost of bank maintenance, prevents associated loss of farmland	reduces sediment, nutrient and bacteria loading (5 to 10 percent)
Buffer strips	0.08	- along ditches and streams — a buffer strip is an integral part of ditch structure and as such helps protect ditch banks, reduces water velocity - along field boundaries ries buffer strips create opportunity for tree windbreaks	reduces sediment and nutrient loading to stream (5 to 10 percent)
Total	5.48		

The effect of urban runoff upon the central Grand and lower Speed river was determined by:

a) simulating, in a water quality river model, the effects of runoff from Brantford, Cambridge, Guelph, Kitchener and Waterloo (Ref. Tech. Report No. 28)
b) carrying out measurements of urban runoff quality in Guelph, Kitchener and Waterloo (Ref. Tech. Report No. 28).

The study concluded that the impact of urban runoff on the dissolved oxygen regime in the central Grand and lower Speed rivers is minor. Similarly, the urban percentage contribution to suspended solids, nutrients and heavy metals in the main river is small, varying from 2 to 6 percent. However, urban runoff did increase bacteria locally at each urban area.

While urban impact is small on the large receiving rivers, urban runoff has a significant impact on the water quality of the small urban streams such as Montgomery and Schneider creeks in Kitchener.

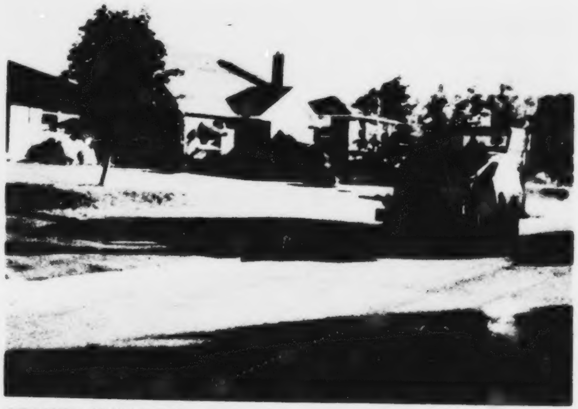
A reduction in pollutants from urban runoff can be accomplished by various modern stormwater management practices (Ref. 14).

Some preventive methods of reducing pollutants from existing urban communities are:

a) the location and eradication of all illegal connections of sanitary and industrial waste effluents to storm sewers through surveillance and remedial measures
b) the reduction of atmospheric emissions which subsequently accumulate on surfaces and are washed off during rain storm or melt events (e.g. more use of non-leaded gasoline)
c) judicious use of sodium chloride as a de-icing agent on roads to lower chloride loads from urban areas
d) the initiation of public-education programs designed to reduce the accumulation of litter and animal wastes on streets, and to promote the proper use of pesticides and fertilizers on urban and agricultural land to reduce pollution from phosphorus, bacteria, and pesticides
e) the implementation of so-called "best management practices" such as improved street sweeping practices to remove accumulated contaminants from streets, and more frequent catch basin sump cleaning.

In newly urbanizing areas, sediment and erosion control plans should be developed and carried out in the construction phase of development using such techniques as mulching and sodding exposed surfaces, especially drainage channels and sedimentation ponds.

Sedimentation ponds could be either 'dry' or 'wet' and installed to be used permanently to capture sediments after the construction stage. Since a significant proportion of the pollutant load of metals and phosphorus is attached to sediment, any sediment control program will reduce the loads of these pollutants as well. Special efforts should be made to control possible chemical and petroleum spills likely from commercial and industrial areas, by providing oil separators and detention ponds.



STREET SWEEPING: Street sweepers reduce urban pollutant loading to streams

Detailed surveys and analyses will be required to determine the most cost-effective method of improving or protecting the water quality of the small urban tributaries.

In the Grand river basin, the pollutant input from urban runoff is small relative to sewage treatment plant and agricultural diffuse sources. While initial priority for pollution control measures at the basin level should be given to these two major sources, municipalities should undertake all practical non-point pollution control measures to improve or protect the water quality of their local watercourses.

STORMWATER MANAGEMENT PONDS: These ponds at Guelph reduce downstream flood flows, recharge groundwater and store sediments from urban runoff.

9.6.3 Practices To Reduce Water Demand

Water Conservation

Diminishing ground water supplies in the central region of the basin plus the high cost of importing lake water emphasize the importance of more efficient utilization of existing water supplies.

For some areas, most notably Kitchener and Waterloo, the adoption of water conservation methods could extend the life of the existing supplies and defer the need for new water supply and sewage treatment plants by approximately five to ten years. Water conservation programs embrace a range of actions that aim at reducing average and maximum day demands. They include new pricing policies, leakage surveys, restrictions on non-essential uses such as lawn sprinkling, and the adoption of water-saving devices in the home such as low demand toilets and restricted shower heads.
At present, the current per capita municipal use for major urban centres ranges from 650 L/capita•d [143 gallons per capita per day (gpcd)] at Brantford to 450 L/capita•d (99 gpcd) at Waterloo. Municipal per capita basin consumption for all serviced communities averages 541 L/capita•d (119 gpcd). With the adoption of various conservation programs, where warranted, it is conceivable that an average per capita rate of consumption of approximately 414 L/capita•d (91 gpcd) can be obtained.

The effect of a moderate water conservation program for a medium population projection is described for the major urban areas. This program assumes a 10 percent reduction of in-house use, a 15 percent reduction in sprinkling plus reductions in industrial use (Ref. Tech. Report No. 26).

The Regional Municipality of Waterloo, in co-operation with the University of Waterloo, is actively pursuing a water conservation program. In particular, the region through an active information program is restricting lawn watering during the summer. Lawn watering is a major cause of high peak uses for which water systems must be designed. It is estimated that a moderate conservation approach for Waterloo and Kitchener would reduce average day demand by 10 percent and maximum day demand by 12 percent. This would defer the needed water supply projects and sewage treatment expansions by approximately five years.

In Cambridge, the adoption of moderate conservation methods would reduce average day demand by 16 percent and maximum day demand by 17 percent.

In Guelph, the industrial water demand has been reduced through the co-operation of the city and individual firms. In this city, conservation methods could reduce average day demand by 13 percent to 21 percent and maximum day demand by 15 percent to 21 percent. However, increasing rates and a move to a constant rate structure are already reducing water demands. System losses appear to be high — 9 percent higher than the provincial average. This loss could be unbilled consumption or system leakage.

The estimated impact of water conservation upon Guelph and Cambridge is higher than for Waterloo and Kitchener because system losses are higher (23 percent), compared to Waterloo and Kitchener (10 percent to 12 percent), and the existing industrial water demand is larger. Both components should be reduced by water conservation.

Because Brantford has the greatest concentration of water intensive manufacturing firms and the lowest water price, per capita consumption rates are the highest observed among the major centres in the basin [636 L/capita•d (14 gpcd)]. Forseeable demands can easily be met from the Grand river and there is no immediate need for water conservation. As in Guelph, losses in Brantford are approximately 9 percent higher than the provincial average.

One component of water conservation pricing policies was examined in more detail. At present, all communities except Waterloo have a decreasing rate structure as quantity increases. A constant rate structure like that of the City of Waterloo may reduce average day and maximum day demand by 2 percent to 7 percent. A rate structure that includes a special summer surcharge for consumption over an average winter consumption, may reduce peak day demand 9 percent at Kitchener and 15 percent at Guelph (Ref. Tech. Report No. 27).

9.6.4 General Water Management Practices

Wetland Preservation

Historically, wetlands have served as important habitats for plants and animals. The basin study has examined wetlands with regard to their usefulness in water management and the need for their preservation. Over 7 percent of the watershed is estimated to be wetlands. Of this total, approximately one-half can be classified as recharge wetlands. These are areas which recharge a limited amount of precipitation into the ground water. The remaining one-half can be classified as discharge wetlands. These areas discharge ground water into the streams and rivers of the Grand river basin.

Only two wetland areas, the Luther marsh and the Eramosa valley wetlands have a major impact upon water management in the Grand river basin. The remaining wetlands are smaller in size and would only have an impact on local ground water and surface water conditions. Detailed site specific studies are required to assess the importance of any individual wetland to the local water resources.

ERAMOSA WETLANDS

The Eramosa valley wetlands border the Eramosa river, acting as a buffer between the adjoining farm lands and the river. These wetlands impede the flood waters sufficiently to reduce flood peaks on the Eramosa river. It was estimated that the wetlands would reduce flood peaks on the Eramosa river by approximately 70 percent. The wetlands aid in improving the river water quality by reducing the transport of suspended sediment and nutrients to the river. The quality is important as the Eramosa river supports a cold water fishery and is used to recharge a shallow aquifer near Arkell to provide additional water supply to Guelph.

While portions of the Eramosa wetlands have been acquired by the Grand River Conservation Authority, additional planning controls and acquisition are required to preserve the remaining unprotected wetlands.

The Luther marsh, located near the headwaters of the Grand river, forms part of a river source area. In the marsh, small amounts of water are recharged to a local aquifer. The Luther wetland serves as a storage area to augment summer flows and to decrease flood flows in the spring in the downstream reaches of the Grand river. It also acts as a filter to trap polluting materials in runoff from adjacent lands.

The preservation of the Luther marsh area has been assured through the acquisition of marshlands by the Grand River Conservation Authority.

Hazard Land Management

Hazard lands are all lands having inherent environmental hazards, such as flood susceptibility, erosion susceptibility, organic soils, high water tables or any other physical condition which by itself or in combination with other conditions is severe enough to cause property damage and/or potential loss of life if those lands were to be developed.

Practices to reduce flood damage are described in Section 9.6.1. The preservation of lands which are composed of organic soils or which exhibit a high water table (wetlands) is discussed in Section 9.6.4.

The protection of steep or erosive slopes from development is required to prevent excessive erosion and/or embankment failure which may cause loss of life, property damage and alteration to adjacent river channels. Development includes the dumping, placing or removal of fill as well as the construction of structures.

Effective management of hazard land areas requires the review of landscape alterations not only to the floodplain land, but the adjacent valley slopes to the top-of-bank.

In this regard, the Grand River Conservation Authority is given authority to regulate the dumping or placing of fill in defined areas under Section 28 (f) of the Conservation Authorities Act. In order to enforce this section of the Act, the Authority must designate the area affected by such actions with fill lines. At present, the Conservation Authority has protected specific areas (wetlands and source areas) by fill lines. However, the addition of fill lines to the Authority's floodplain maps is necessary to protect valley slopes.

Once the appropriate technical information is available, hazard lands can then be incorporated in municipal planning documents in order to provide accessibility of information to the general public and co-ordination between the Conservation Authorities Act and the Planning Act.

Protection of Ground Water Recharge Areas

The shallow and deep aquifers tapped by the Regional Municipality of Waterloo and the City of Guelph for water supply can be viewed as large underground reservoirs. Shallow aquifers are replenished or recharged by precipitation that infiltrates into the ground directly over the aquifers. Deep aquifers usually obtain their recharge from precipitation that has infiltrated in areas some distance away. At present, the areas of infiltration consist largely of agricultural lands with a small portion of land in urban use.

Land use practices at some locations can pose a significant threat to aquifer water quality and to a lesser extent, aquifer yield.

The disposal of waste products, particularly from industries, in landfill sites, as well as chemical spills in areas of sands and gravels, pose serious threats to the safe use of aquifers for water supply. Extreme care should be taken to ensure that waste disposal sites are constructed to prevent contamination of water supply aquifers. Also, waste disposal sites should be monitoried to ensure that there is no contamination of the local aquifers.

Some reductions in shallow aquifer yields may occur in urban areas where construction of impervious roads, parking lots and buildings have often reduced the amount of precipitation that can infiltrate into the soil. This loss of aquifer recharge can be partially restored by the use of stormwater recharge ponds and pervious driveways and parking lots.

10. EFFECTIVENESS OF MAIN PLANS

The main water management plans satisfy, to varying degrees, the basin study objectives. This chapter describes how well each plan fulfills these objectives and discusses the risks and uncertainties inherent to each plan.

10.1 Flood Damage Reduction

For each plan, reduction in basin-wide flood damages has been measured by calculating the percentage reduction in the existing $980,000 average annual flood damages. The average annual damages are those which would occur, on the average, over a 100 year period or longer. On a yearly basis, flood damages are much less than average annual flood damages. It is the periodic, large flood events which increase the average annual flood damages (Appendix F).

Plans A, B2 and D reduce average annual flood damages in the six major flood centres by over 91 percent. They increase the level of protection at Cambridge (Galt) and Brantford to withstand floods greater than those occurring, on the average, once in a hundred years with an elevation less than or equal to the regional storm floodline (Table 10.1). The dyking and channelization projects of plans A, B2 and D are the most cost effective means of reducing flood damages (Fig. 10.1). Most of the reduction is provided by dykes and channelization at Cambridge (Galt) and Brantford where over 85 percent of the average annual flood damages occur. The dyking systems proposed for Paris, Caledonia, Dunnville and New Hamburg produce fewer benefits per dollar spent (Table 10.2). The Montrose reservoir by itself, is the most effective of all the proposed reservoir systems in reducing flood damages. It generates an average 55 percent reduction in average annual flood damages.

In plan C1, the St. Jacobs reservoir provides a maximum flood reduction of 50 percent. Plan C2, the Montrose small single-purpose reservoir option, provides a slightly higher maximum flood damage reduction. Plan C3, the Montrose large single-purpose reservoir with almost three times more storage available than plan C2, produces a maximum of only 3 percent more damage reduction than plan C2. This small additional reduction in damage occurs as a result of the uncontrolled local inflows which occur downstream of the reservoirs above the flood damage centres. At Montrose, flood control storage greater than approximately 24.7 million cubic metres (20,000 acre-ft) has little effect on reducing downstream flood damages.

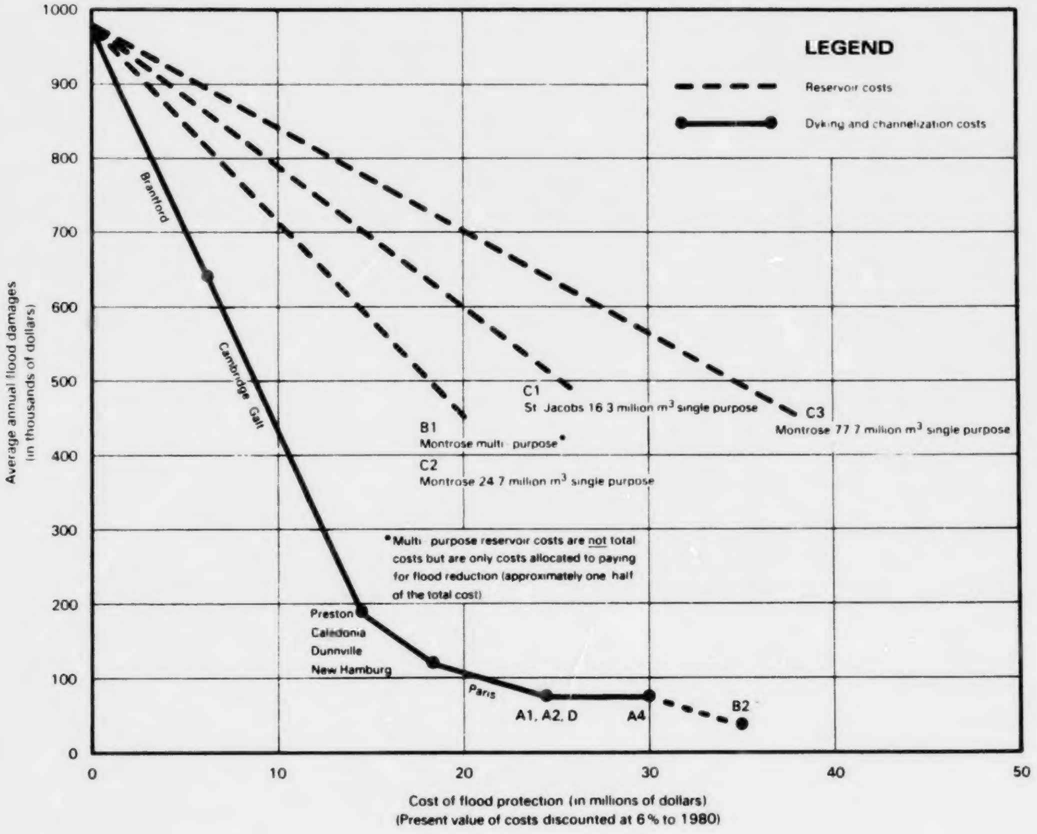


Figure 10.1. Flood damage reduction cost - effectiveness.

Table 10.1
Average Annual Reduction in Flood Damages
($1979)

Plan	Average Annual** Damages	Reduction in Average Annual Damages	% Objective Achieved	*Level of Protection Provided at Cambridge (Galt) and Brantford
Existing	980,000	N/A	N/A	5 yr.
A1,2,3,4	85,000	895,000	91%	>100 yr.
B1	430,000-455,000	550,000-525,000	56%-54%	10 yr.
B2	35,000	945,000	96%	>100 yr.
C1	490,000-495,000	490,000-485,000	50%-49%	10 yr.
C2	430,000-455,000	550,000-525,000	56%-54%	10 yr.
C3	425,000-430,000	555,000-550,000	57%-56%	10 yr.
D	85,000	895,000	91%	>100 yr.

* Average frequency of occurrence of floods producing some damages.

** Damages do not include damages caused by ice jams.

N/A Not Applicable

Table 10.2 Reduction in Flood Damage Costs in Major Flood Damage Centres by the Main Plans
(Present Value of Damages in Millions of 1979 Dollars at 6% Discount)

Flood Damage Centres	Existing Flood Damage Costs	Reduction in Flood Damage Costs					
		Plans A & D	Plan B1	Plan B2	Plan C1	Plan C2	Plan C3
Cambridge(Galt)	7.72	7.09	4.55	7.32	3.60	4.55	4.55
Cambridge(Preston)	0.24	0.24	0.00	0.24	0.00	0.00	0.00
Paris	1.02	0.90	0.61	0.96	0.45	0.45	0.61
Brantford	5.68	5.09	3.26	5.56	3.00	3.10	3.26
Caledonia	0.06	0.06	0.02	0.06	0.01	0.01	0.02
Dunnville	0.32	0.32	0.21	0.32	0.16	0.16	0.21
New Hamburg	0.39	0.39	0.39	0.39	0.39	0.39	0.39
Total	15.43	14.09	9.04	14.85	7.61	8.66	9.04

Single-purpose reservoirs plans C1 and C3 are less cost-effective than the multi-purpose Montrose reservoir, plan B1 (Fig. 10.1). In this comparison, only one half of the Montrose costs are allocated to paying for flood damage reductions whereas the entire costs of the single-purpose reservoirs C1 and C3 are included as costs to reduce flood damages (appendix C).

Variation in Future Flood Damages

Several factors could cause an increase in the average annual flood damages, including an increase in the number of buildings erected in the floodplain or an increase in the frequency of flood flows. This study assumes that existing floodplain regulations will restrict future construction and that any further development permitted within the floodplain will not materially affect average annual flood damages (Appendix F). However, an increase in the frequency of flood flows due to changing land use is far less predictable and could result in increases in the average annual flood damages (Ref. 1).

10.2 Maintain Adequate Water Quality

In comparing the various plans in terms of water quality, primary emphasis has been placed on the problems caused by oxygen-consuming materials and nutrient enrichment. The methods that can be used to achieve the water quality objective for dissolved oxygen, will alleviate many of the water quality problems created by the various pollutants outlined in Chapter 6, particularly toxic ammonia. Remedial measures aimed specifically at controlling certain non-point and urban sources of pollution are common to all plans and are dealt with in Chapters 7 and 9.

Oxygen-demanding pollutants from sewage treatment plants and areas of excessive aquatic plant growth combine to reduce dissolved oxygen concentrations in the central Grand river for 40 kilometres (25 miles) between Waterloo and Paris and in the Speed river for 20 kilometres (12 miles) between Guelph and Cambridge (Preston). Therefore, these two most seriously degraded stretches of the river system were selected for intensive investigation and subdivided into twenty-one segments for modelling purposes (Fig. 10.2).

The water quality simulation model mathematically simulates water quality conditions in the twenty-one river reaches, incorporating a wide variety of variables including streamflow, waste loading, water temperature, and aquatic plant growth (Appendix D). A review of water quality records shows that the most serious degradation occurs during the late spring, summer and early autumn months when natural streamflows are lowest, water temperatures are highest, and plant growth is maximum. As a result, the model was run to predict daily water quality conditions for the four month period from June to September. Output from the model provides information on the percentage of time within any given month that the provincial dissolved oxygen objective (i.e. 4 mg/L at 25°C) is not achieved; the degree of non-compliance, (i.e. how low levels actually dropped); and the spatial extent of water quality degradation.

In comparing and evaluating the effectiveness of the plans for improving water quality, two different types of years were examined — the "worst" year, (ie. the one year out of twenty years of simulation which exhibits the most degraded instream dissolved oxygen conditions) and the "average" year which reflects conditions that could be expected to occur during the majority of years (Appendix D). Furthermore, output from the model indicates that during most years, the most critical conditions of dissolved oxygen depression and nuisance aquatic plant growth occur during August.

Accordingly, water quality conditions which occur during the month of August are useful to compare the effectiveness of the different plans.

Grand River — Central Basin

Plans A, C, and D improve water quality conditions in the central Grand river basin by reducing oxygen-demanding waste loadings and nutrient inputs through the use of advanced sewage treatment. Initially, plan B achieves water quality improvements by augmenting streamflow with water from the Montrose reservoir. Further improvements are made under plan B by adding advanced sewage treatment at Kitchener in the year 2001 and in Waterloo in the year 2021.

The impact of water quality management plans on dissolved oxygen levels for the average and worst years in the central Grand river basin are detailed for the medium population projection (Fig. 10.3 and 10.4). The beneficial effects of plans A, C, and D and plan B are compared to existing conditions, that is, conditions that would result if advanced sewage treatment or additional flow augmentation were not provided.

Several important facts become apparent:

1) the dissolved oxygen objective is not achieved fully by any plan
2) all plans result in improved water quality conditions both in terms of time of non-compliance with the dissolved oxygen objective and the magnitude of violation in terms of minimum concentrations
3) plan B has the most beneficial impact on water quality, particularly after 2001, when advanced sewage treatment is incorporated at the Kitchener sewage treatment plant
4) oxygen-demanding waste discharges from the Kitchener sewage treatment plant in combination with

nuisance aquatic plant growths result in serious degradation near Doon (reach 5) and through Cambridge (Galt) (reach 14)

5) low dissolved oxygen levels in the vicinity of Glen Morris (reach 16) result primarily from aquatic plant respiration. The water quality components of plans A, C, and D do not appear to provide substantial improvement at this location, whereas the flow augmentation from the Montrose reservoir (plan B) does have beneficial effects
6) during the worst year, the occurrence of dissolved oxygen levels less than 1 mg/L (near septic conditions) are greatly reduced by plans A, C, and D and virtually eliminated by plan B. All plans also substantially reduce the lengths of time when concentrations are less than 2 mg/L (Fig. 10.4).

Figure 10.5 illustrates the impacts of the plans on reach 5, the most degraded zone in the central basin. Under both average and worst year conditions, conventional (existing) treatment results in continuing degradation over the next fifty years. The benefits of the plans in terms of increasing the very low (less than 2 mg/L) dissolved oxygen levels are clearly shown. Plan B further improves dissolved oxygen levels after the year 2001 with the addition of advanced waste treatment at Kitchener significantly increasing the benefits of flow augmentation. In terms of water quality, the plans produce improvements over the next twenty years and a slight tread towards degradation for plans A, C and D after that time as populations and thus loadings from the sewage treatment plants increase. However, the degree of water quality impairment remains much less than conditions that exist today.

The effects of the treated wastewater discharges from the Paris and Brantford sewage treatment plants were included in the mathematical simulation model. The relatively small discharge from Paris does not result in water quality degradation during the average or worst years, either today or with future population projections.

The Brantford sewage treatment plant discharges its treated waste to an area of the river with a high assimilative capacity and streamflow and low levels of aquatic plant and algal growth. As a result, dissolved oxygen levels now and in the future do not fall below 4 mg/L for either average or worst year conditions. Simulation modelling indicates that treatment beyond conventional activated sludge treatment is not required to maintain satisfactory dissolved oxygen levels below Brantford. However, nitrification may be required to prevent ammonia toxicity at some point in the future.

Meeting the Provincial Water Quality Objectives

None of the plans meets the dissolved oxygen objective of 4 mg/L in the critical reaches of the central Grand basin continuously. Achieving this objective fully would require the virtual elimination of oxygen-demanding wastes from all sources as well as substantial reductions of phosphorus (to about 0.1 mg/L) in the sewage effluents and runoff from all non-point sources.

Phosphorus reduction by itself from either land drainage or sewage treatment plants provides little improvement in dissolved oxygen levels. It must be accompanied by an equivalent reduction in oxygen-demanding wastes. For example, an 80 percent reduction of phosphorus from rural diffuse sources upstream of Waterloo would result in an increase of only 0.5 mg/L in oxygen concentrations in the central Grand river reach. It is highly doubtful that such a large reduction is technically or economically feasible at the present time.

While it is technically possible, the reduction of phosphorus and oxygen-demanding waste loadings from sewage treatment plants to 0.1 mg/L is extremely expensive and even then, without upstream controls, the dissolved oxygen objective would not be met fully (Appendix E).

While not achieving the dissolved oxygen objective totally, the plans result in a substantial improvement in water quality by minimizing the critically low (less than 2 mg/L) dissolved oxygen levels and reducing the total time of non-compliance with the provincial objective at all locations in the central basin. In addition, the plans have beneficial effects for other water quality parameters. The advanced sewage treatment (nitrification) of plans A, C and D and the dilution from flow augmentation of plan B eliminate problems related to toxic un-ionized ammonia. Sewage effluent filtration further reduces suspended particulate matter as well as associated phosphorus, metals and trace organic chemicals. Nitrification and filtration improve the disinfection efficiency of chlorine, thus reducing bacteria in the sewage treatment plant discharges and costs of chlorination.

Water Quality Benefits

If the provincial water quality objective for dissolved oxygen cannot be maintained at all times throughout the central basin by plans A, B, C or D, what then, are the benefits of the improved water quality conditions achieved by these plans? The benefits lie principally in the improvement of the aquatic habitat for fish and other organisms in aesthetically more attractive watercourses.

A dissolved oxygen index incorporating time, magnitude (concentration), and spatial extent of non-compliance with the dissolved oxygen objective was developed specifically for the basin study in order to assess each plan's improvement in conditions for aquatic life (Appendix E).

Based on toxicity information regarding low dissolved oxygen levels, the dissolved oxygen index was subdivided into categories (Ref. Tech. Report No. 13). A value

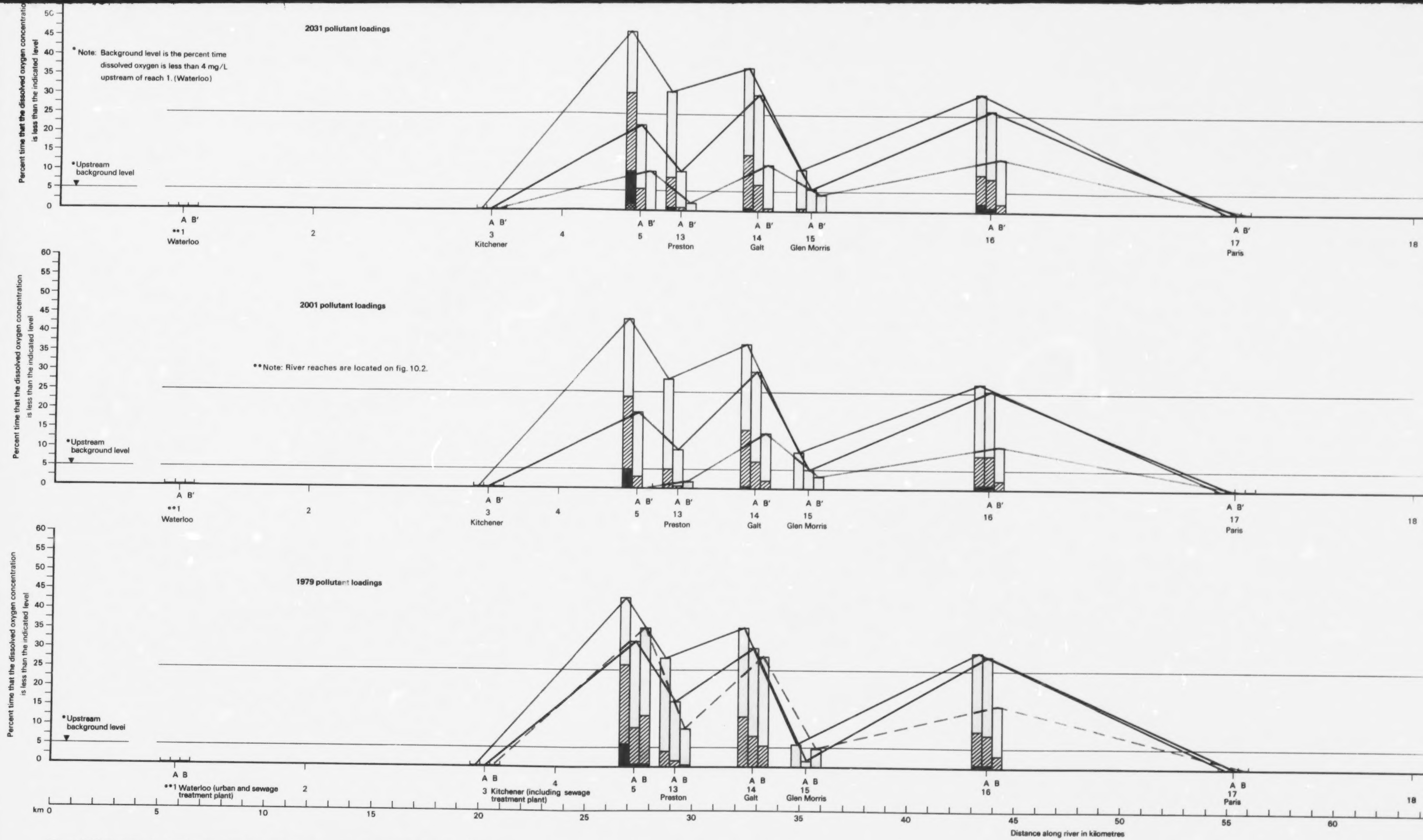
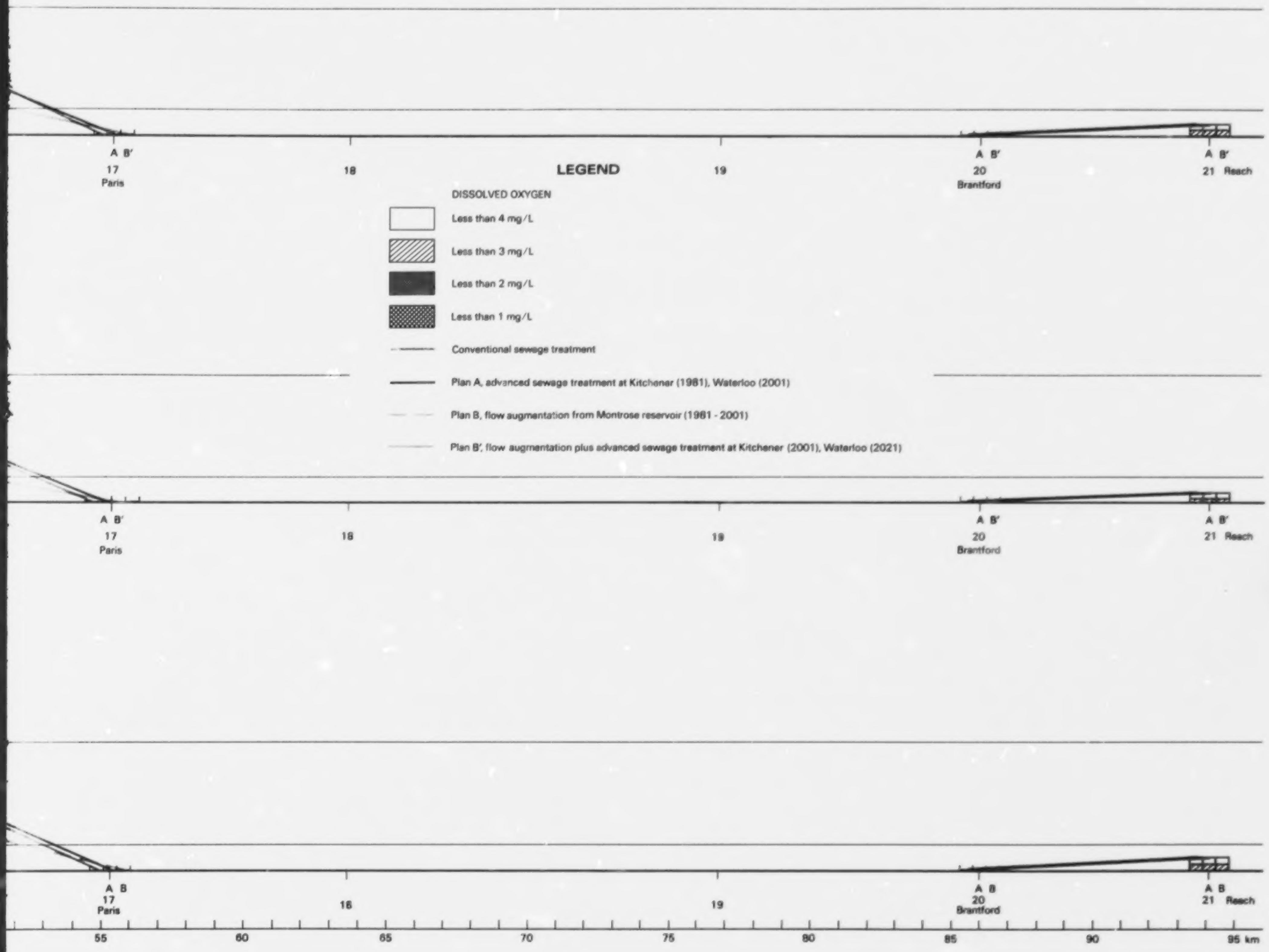


Figure 10.3. Variation in dissolved oxygen levels for the Grand River during the month of August, average year conditions (Medium population projections).


A B'
17
Paris
18
19
20
Brantford
21 Reach
LEGEND
DISSOLVED OXYGEN
Less than 4 mg/L
Less than 3 mg/L
Less than 2 mg/L
Less than 1 mg/L
Conventional sewage treatment
Plan A, advanced sewage treatment at Kitchener (1981), Waterloo (2001)
Plan B, flow augmentation from Montrose reservoir (1981 - 2001)
Plan B', flow augmentation plus advanced sewage treatment at Kitchener (2001), Waterloo (2021)
A B
55
60
65
70
75
80
85
90
95 km

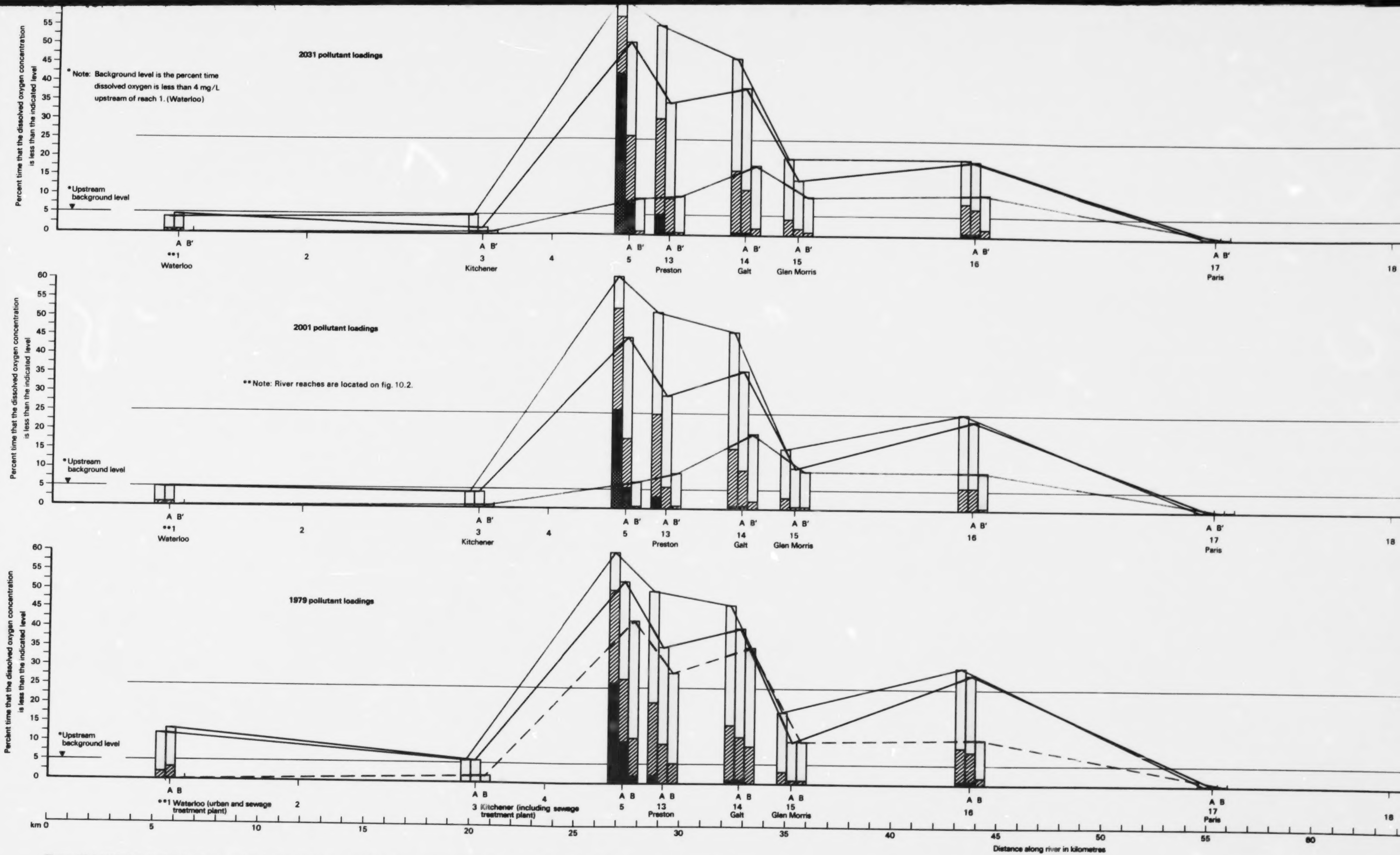
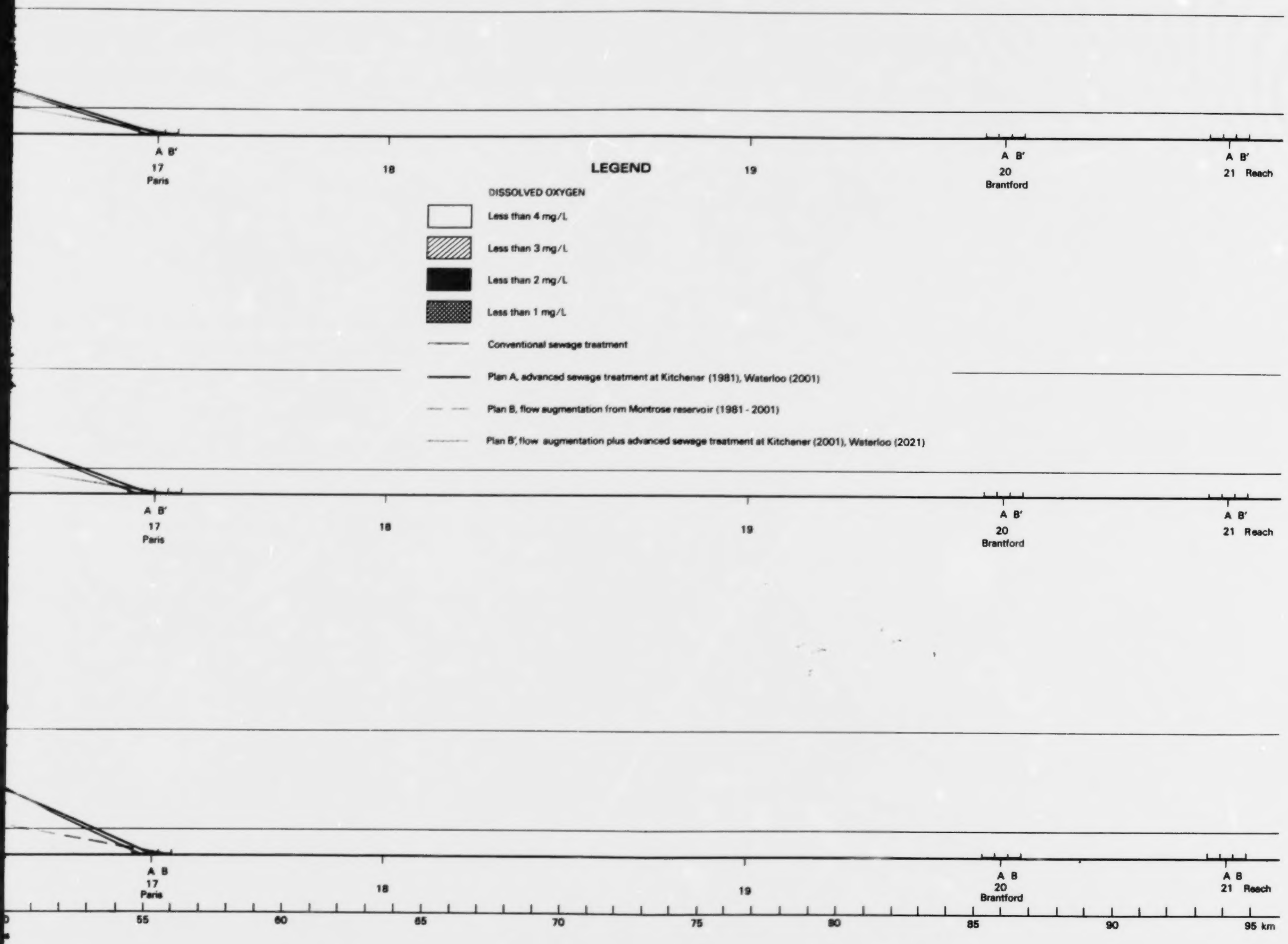


Figure 10.4. Variation in dissolved oxygen levels for the Grand River during the month of August, worst year conditions (Medium population projections).



A B'
17
Paris
18
LEGEND
19
A B'
20
Brantford
A B'
21 Reach
DISSOLVED OXYGEN
Less than 4 mg/L
Less than 3 mg/L
Less than 2 mg/L
Less than 1 mg/L
Conventional sewage treatment
Plan A, advanced sewage treatment at Kitchener (1981), Waterloo (2001)
Plan B, flow augmentation from Montrose reservoir (1981 - 2001)
Plan B', flow augmentation plus advanced sewage treatment at Kitchener (2001), Waterloo (2021)
A B'
17
Paris
18
19
A B'
20
Brantford
A B'
21 Reach
A B
17
Paris
18
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A B
20
Brantford
A B
21 Reach
55
60
65
70
75
80
85
90
95 km

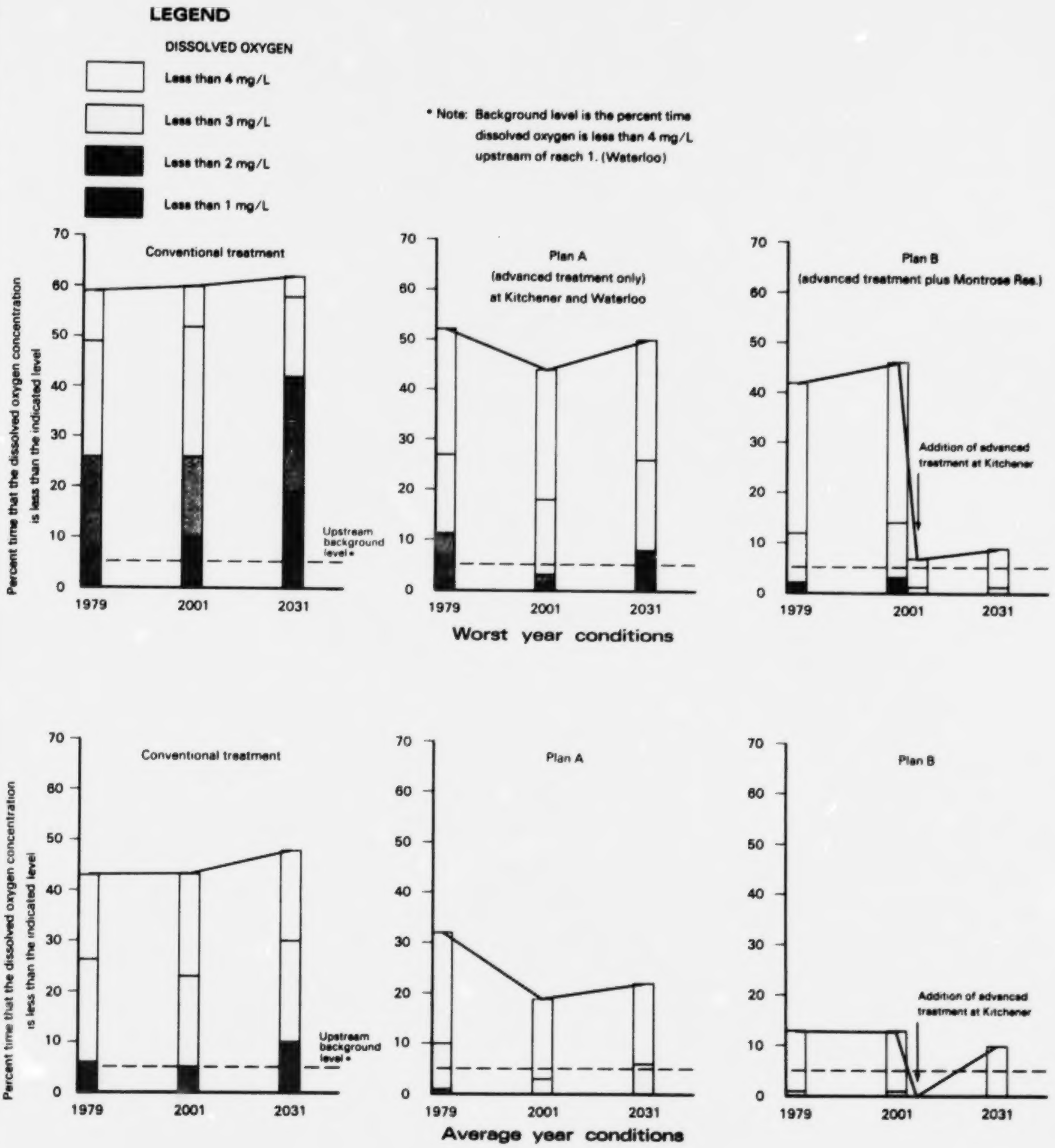
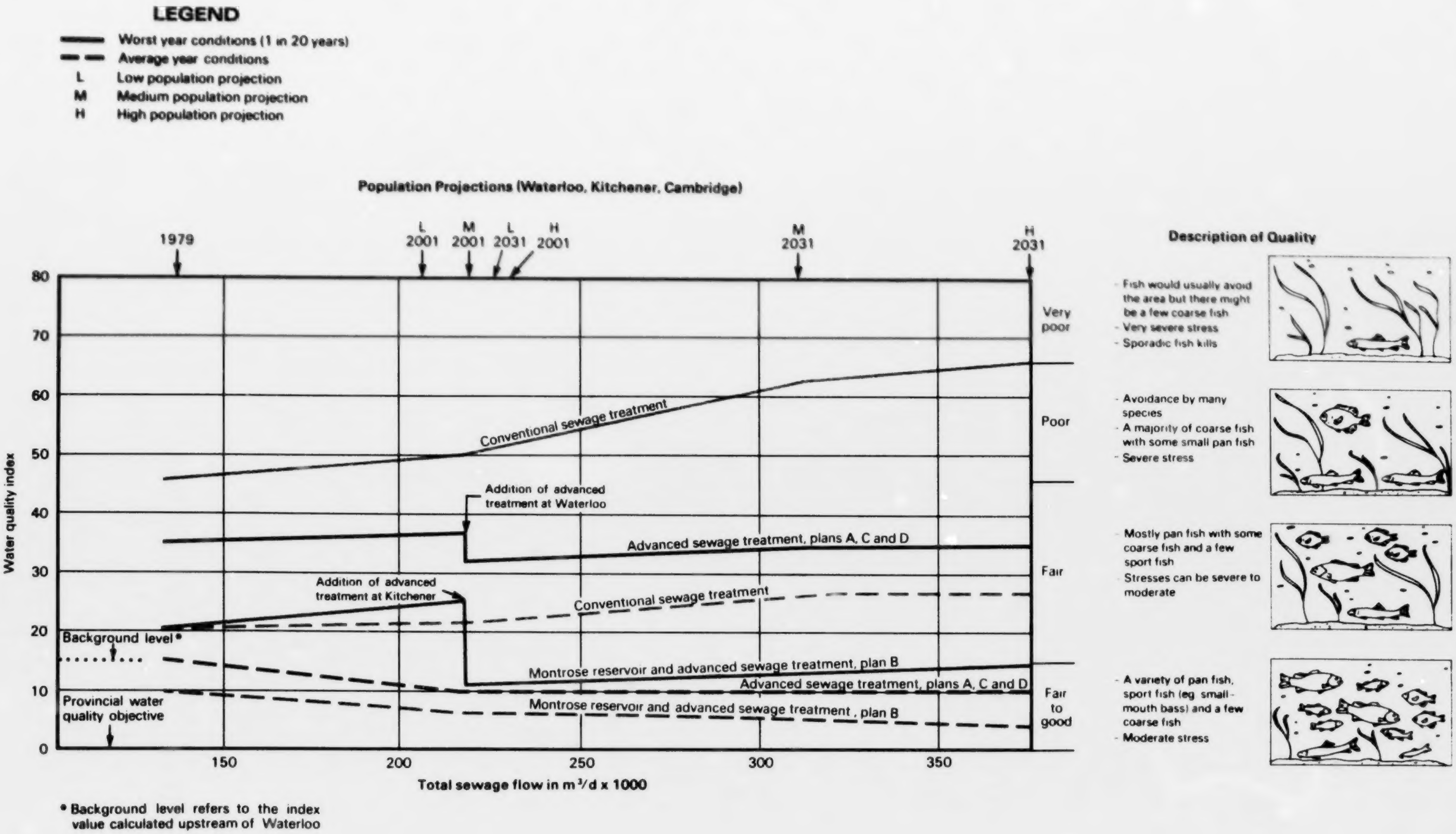


Figure 10.5. Grand River – Variation in minimum dissolved oxygen levels at Reach 5 in the month of August for a medium population projection.



* Background level refers to the index value calculated upstream of Waterloo

Figure 10.6 Grand River – Variation of the dissolved oxygen water quality index with population growth and sewage flow.

greater than 45 on the index represents "poor" quality, unsuitable for the healthy survival of desirable fish species. At the other end of the scale, an index value of 0 represents "good" conditions where the 4 mg/L dissolved oxygen objective is always met. Figure 10.6 shows the index, a descriptive and visual representation of conditions found for each category within the index, and the quality conditions that would be achieved by each plan over the next fifty years.

Based on continuous dissolved oxygen monitoring records for a station located at Kitchener (Bridgeport), summer water quality at the head of the critical central Grand river reach is represented by an index value of 16.7 representing "fair to good" conditions.

For the "do nothing" option; that is, the application of conventional treatment without additional treatment or flow augmentation, dissolved oxygen conditions would fall into the "fair" range during average years, and drop to "poor" during the worst year. As sewage flow increases with urban growth, the dissolved oxygen conditions would degrade slightly for average conditions but would worsen quite markedly for worst year conditions.

With plans A, C, and D, advanced sewage treatment at the major sewage treatment plants would result in a "fair to good" rating during the average year and the river could support a variety of sport fish. In a worst year, dissolved oxygen conditions would drop to the "fair" category and it is reasonable to suspect that sport fish would avoid the areas of lowest dissolved oxygen such as reaches 5, 13, 14, and 16.

Plan B offers the best water quality conditions in terms of the dissolved oxygen index. In an average year dissolved oxygen conditions would fall into the "fair to good" category, to the year 2031. A variety of sport fish could be expected to be found throughout the central basin reach during the average year. During the worst year, water quality would degrade to "fair" in the year 2001. With the implementation of advanced treatment at Kitchener in 2001, conditions would return to "fair to good".

To summarize, all four plans produce improvements in water quality over conventional treatment for both the average and worst year conditions. Plan B clearly provides the best conditions for fish and aquatic life, particularly after the year 2001, when dissolved oxygen would always fall into the "fair to good" range. No plan achieves fully the provincial water quality objective for dissolved oxygen of 4 mg/L — a level that can be achieved only by drastic reductions of oxygen-demanding wastes and phosphorus from all point and non-point sources.

Although plans B1 and B2 produce higher water quality conditions in the central Grand river than the other plans, they would cost more than plan A1 by $8 million and $29 million respectively, and would cause some detrimental social and environmental impacts in the northern part of the basin. Within the Montrose reservoir, there would be an adverse impact on water quality because conditions would encourage nutrient enrichment, bottom water oxygen depression, and algal growth in the fall. These conditions are presently observed in the existing major reservoirs.

The Speed River Basin

The lower Speed river from the Guelph sewage treatment plant to the confluence with the Grand river has low summer dissolved oxygen levels resulting from oxygen-demanding wastewater discharges from the Guelph sewage treatment plant and the respiration of nuisance aquatic plants which are stimulated by the nutrients discharged from the treatment plant.

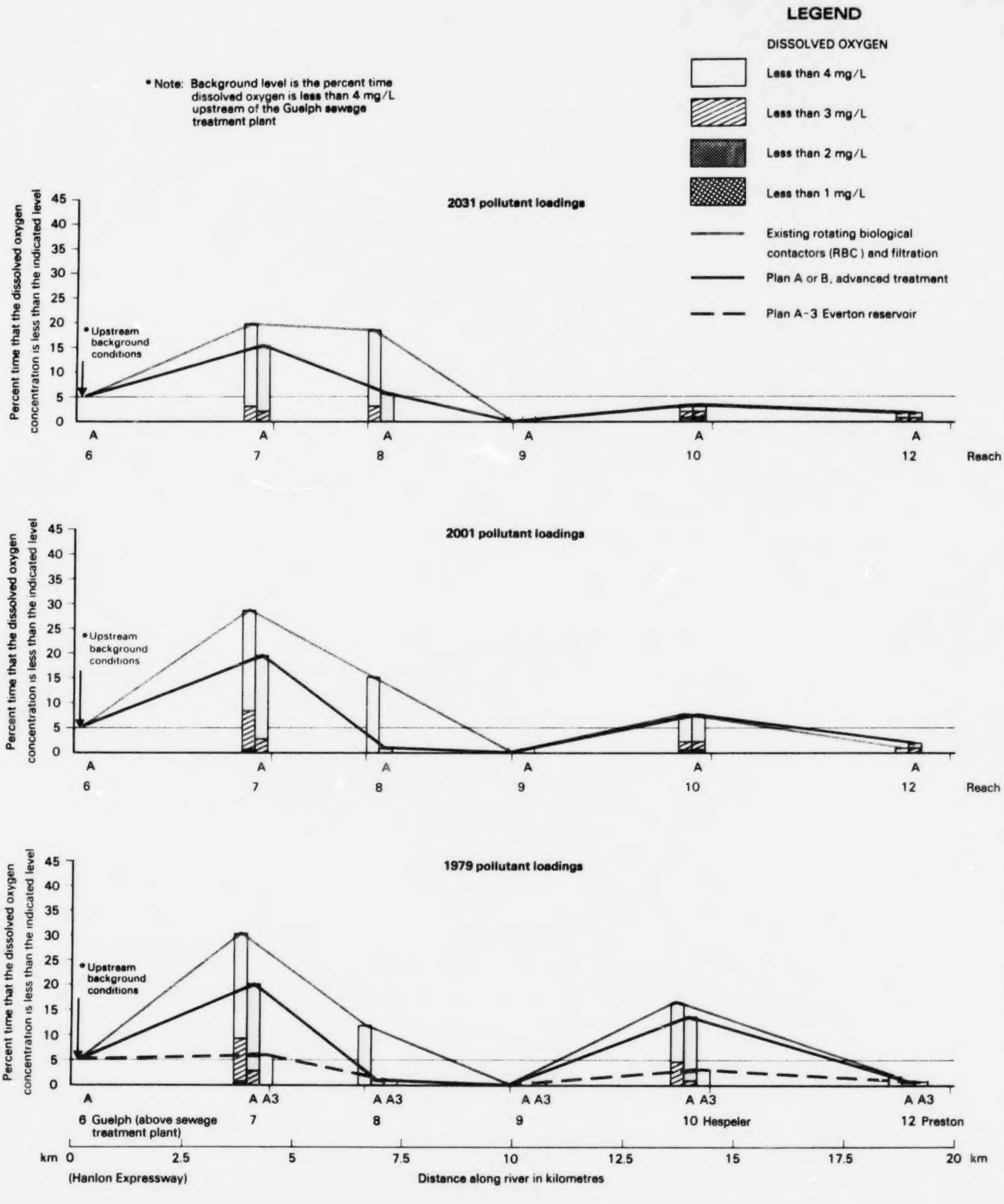
The City of Guelph has recently incorporated nitrification facilities to reduce the oxygen demanding and toxic ammonia effluents from its sewage treatment plant. This facility will substantially improve water quality. However, the dissolved oxygen simulation model shows that even with the new treatment at Guelph, severe oxygen depressions could continue to occur from Guelph to Cambridge (Preston), largely as a result of aquatic plant growth.

The basin study examined two alternatives to improve dissolved oxygen levels in the lower Speed river. The first provided additional treatment to reduce phosphorus discharges at the Guelph sewage treatment plant and thereby reduce the aquatic plant growth downstream. This option was incorporated into the cost estimates for all plans. The second involved additional phosphorus removal at Guelph plus increased streamflow augmentation from a reservoir located upstream from Guelph on the Eramosa river near Everton (plan A3).

The impacts of these two alternatives for the average and worst year conditions on the Speed river between Guelph and Cambridge (Preston) are shown for the medium population projection (Fig. 10.7 and 10.8). Simulation of additional augmentation from the Everton reservoir was carried out for 1979 conditions but not for the next fifty year planning horizon, but the beneficial effects would likely continue over this period. The beneficial effects of each alternative are compared to simulated existing conditions which incorporate the operation of the RBC nitrification units at the Guelph sewage treatment plant.

Several interesting results emerge:

1) the dissolved oxygen objective is not achieved by any plan. In fact, even with the removal of the sewage treatment plant discharge (diverting its



* Note: Background level is the percent time dissolved oxygen is less than 4 mg/L upstream of the Guelph sewage treatment plant

Figure 10.7. Variations in dissolved oxygen levels for the Speed River during the month of August, average year (Medium population).

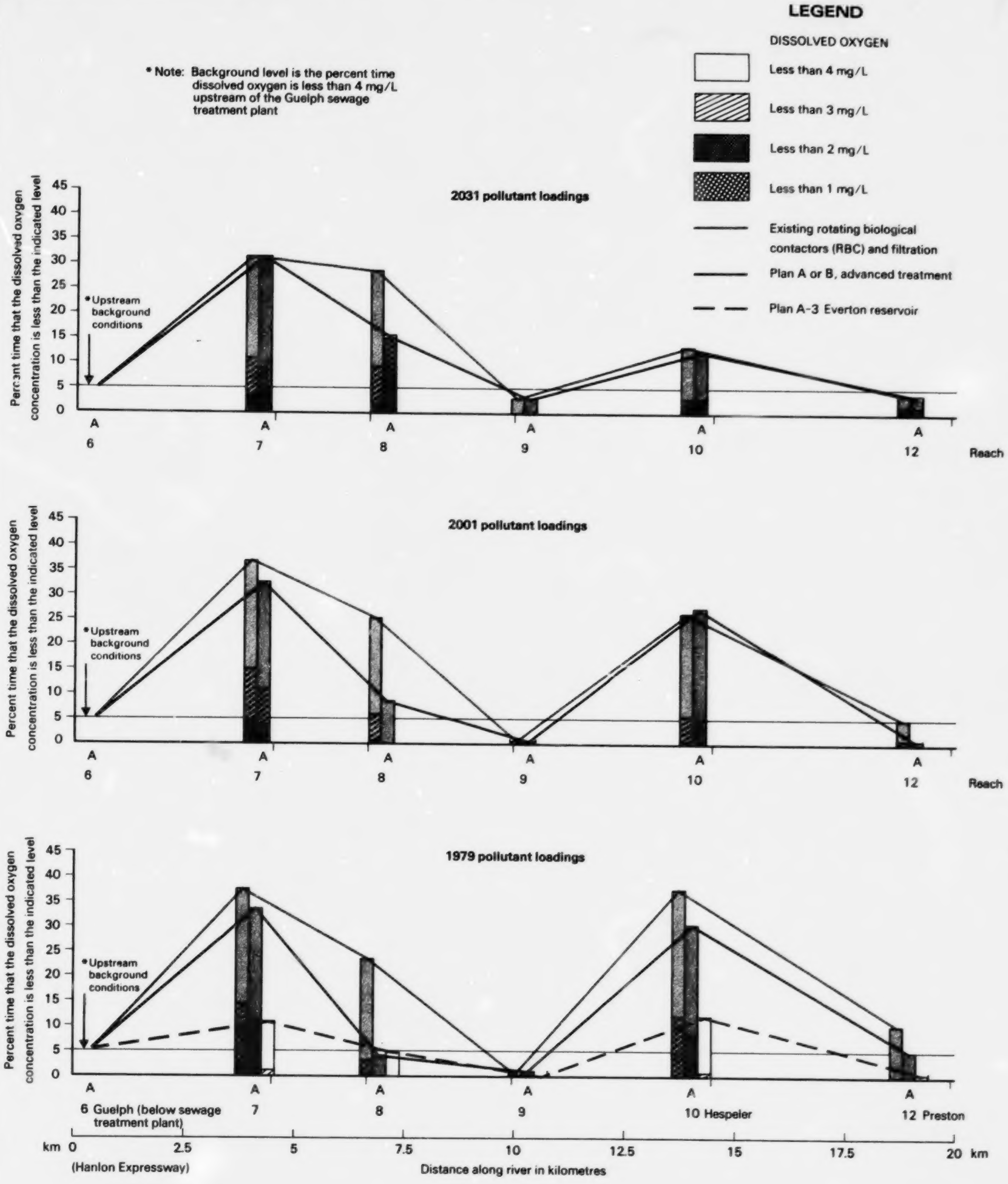


Figure 10.8. Variations in dissolved oxygen levels for the Speed River during the month of August, worst year (Medium population).

discharge to the Grand river), the 4 mg/L objective would not be met at all stations

2) the most seriously degraded reaches are 7 and 8 downstream from the Guelph sewage treatment plant and reach 10 just north of Hespeler. Respiration of nuisance aquatic plant growth is likely the most significant cause of degradation in these areas. However, oxygen-demanding wastes from Guelph contribute to low dissolved oxygen levels at reaches 7 and 8 and impoundments at Hespeler may contribute to degradation at reach 10
3) the treated wastewater discharge from the Hespeler sewage treatment plant appears to have little effect on dissolved oxygen levels
4) during both the average and worst year, existing (RBC) treatment shows an improvement in conditions between 1979, 2001 and 2031. The apparent explanation of this phenomenon is the beneficial effects (i.e. turbulence, additional aeration) of additional flow in the river resulting from higher hydraulic loadings (treated sewage flow) from the Guelph sewage treatment plant as population grows
5) additional phosphorus removal at the Guelph sewage treatment plant and flow augmentation from the Everton reservoir show substantial benefits for both the average and worst year. Additional phosphorus removal alone shows substantial improvement at reach 8 but is of limited benefit at reaches 7 and 10, particularly during the worst year and in the future.

The impact of additional phosphorus removal and flow augmentation (plan A3) at reach 7, the most degraded zone in the lower Speed river is illustrated in Figure 10.9. Water quality conditions will be improved to various degrees in this reach over the next fifty years depending on which plan is implemented. The benefit of plan A3 (Everton reservoir option) in terms of percent time in nonreservoir option) in terms of percent time in noncompliance with the dissolved oxygen objective and magnitude (concentration) of non-compliance, is significant. Some benefit for the average year conditions is expected with additional phosphorus removal alone but the benefit is very limited under worst year conditions.

Meeting the Provincial Water Quality Objective

To date, there has been insufficient opportunity to adequately measure directly the beneficial effects on water quality of the rotating biological contactors and sand filtration facilities recently installed at the Guelph sewage treatment plant. The simulation model indicates that the RBCs and filters will result in measurable improvements in water quality by eliminating the long periods of near-anoxic (zero dissolved oxygen) conditions that occur during most years. The model predicts, in fact, that dissolved oxygen will seldom fall below 2 mg/L.

The utilization of either advanced phosphorous treatment or phosphorus treatment plus flow augmentation by the Everton reservoir would not consistently achieve the 4 mg/L dissolved oxygen objective throughout the lower Speed river. However, under average year conditions the latter alternative would come very close to meeting the provincial water quality objectives for dissolved oxygen at most stations.

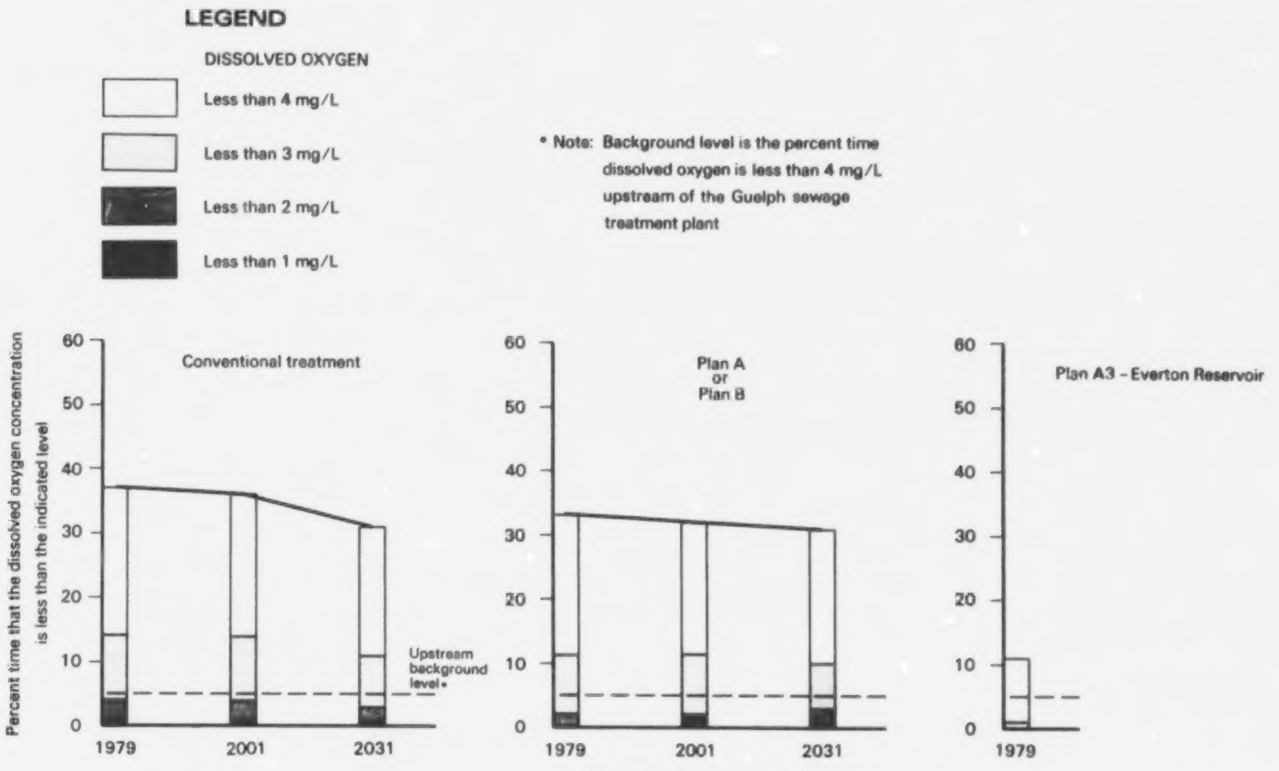
Several additional alternatives were considered to increase dissolved oxygen levels in the lower Speed river including: extremely sophisticated sewage treatment at the Guelph sewage treatment plant (total phosphorus reduction to 0.05 mg/L); removal of the sewage treatment plant discharge from the Speed river (diversion of discharge to the Grand river); and stringent control of all upstream oxygen-demanding waste and phosphorus sources, virtually simulating natural undisturbed conditions.

None of these alternatives increased predicted minimum dissolved oxygen enough to meet the 4 mg/L objective consistently throughout the lower Speed river. Physical conditions of the lower Speed river, such as rocky stream beds, shallow water depths, and lack of shading are naturally conducive to aquatic plant growth. Although documentation could not be found, it is speculated that abundant growths of aquatic plants and attendant lowered night-time dissolved oxygen levels probably occurred in the lower Speed river prior to rural and urban development in the basin. Short of physically removing the aquatic plants or introducing oxygen directly to the river, continuous compliance with the dissolved oxygen objective is technically infeasible.

Water Quality Benefits

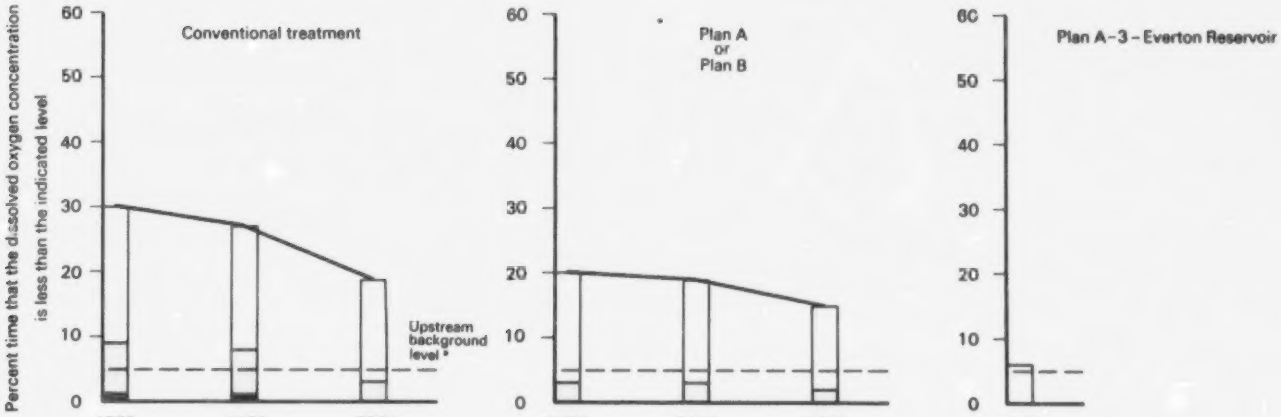
Although neither the advanced treatment option nor the advanced treatment plus additional flow augmentation option consistently achieves the provincial dissolved oxygen objective, each offers measurable benefits when compared to existing conditions. The dissolved oxygen index employed in the central Grand river assessment was applied to the lower Speed river as well (Figure 10.10).

With existing sewage treatment facilities at Guelph (including nitrification), dissolved oxygen conditions during the worst year for all population projections over the fifty year planning horizon, fall into the "very poor" range. No fish, with the exception of a few coarse species such as carp, could survive in these conditions and most desirable sport species would avoid the area. In the average year, conditions are substantially better, falling into the "fair" range. As the population of Guelph increases and more highly-treated sewage is discharged,



* Note: Background level is the percent time dissolved oxygen is less than 4 mg/L upstream of the Guelph sewage treatment plant

Worst year conditions



Average year conditions

Figure 10.9. Speed River – Variation in minimum dissolved oxygen levels at Reach 7 in the month of August for a medium population projection.

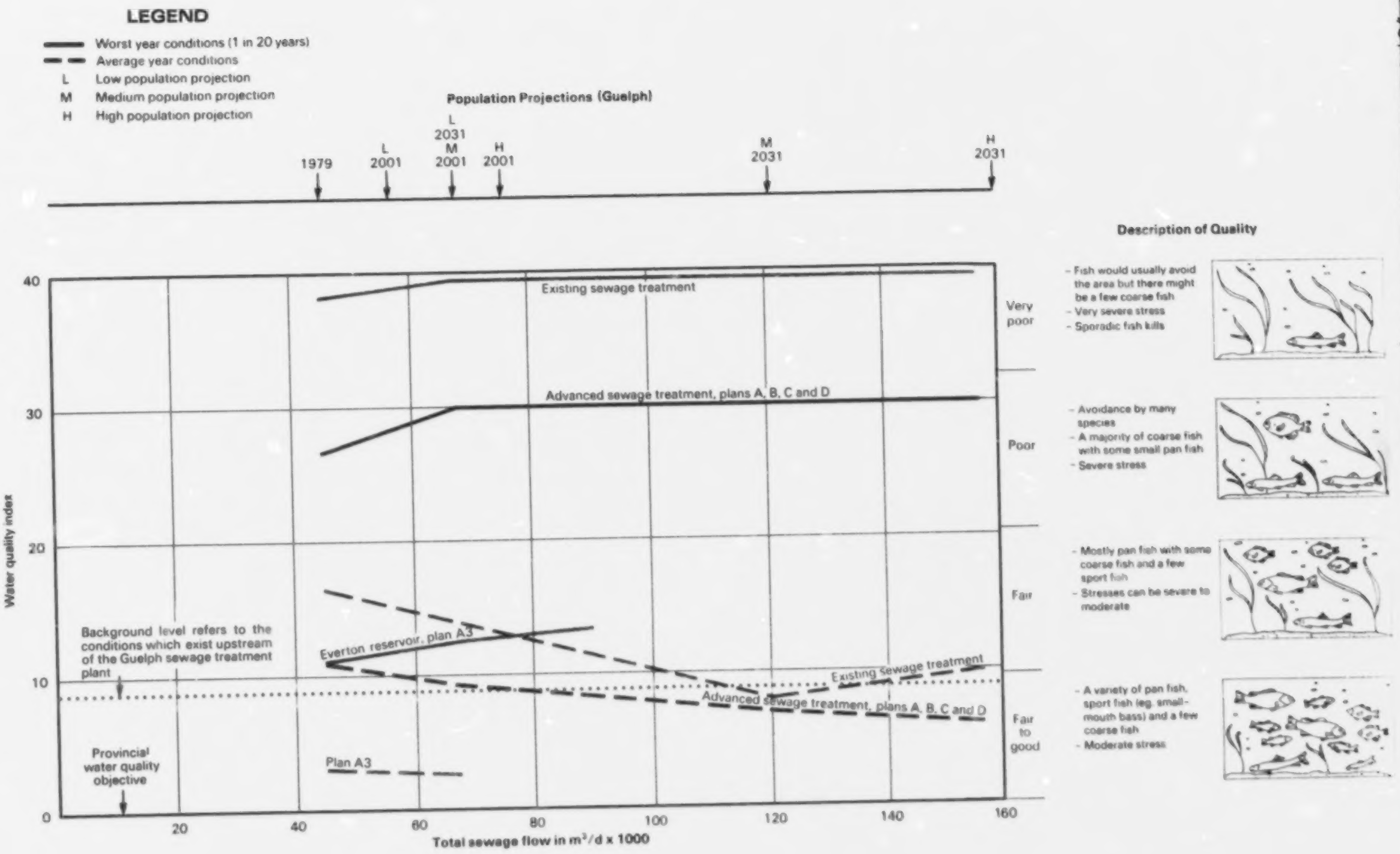


Figure 10.10. Speed River–Variation of the dissolved oxygen water quality index with population growth.

an unusual phenomenon is simulated by the model for average years — the assimilative capacity of the river is increased and water quality conditions are upgraded to the "fair to good" range. Some warm-water sport fish could be expected to be found in the river.

Advanced treatment results in some improvement over existing conditions but, during the worst year, conditions are still rated as "poor" and only coarse fish and some warm-water sport fish would be able to withstand the severe stresses associated with low oxygen levels. During average years, advanced treatment would improve conditions to the "fair" and "fair to good" ranges and a variety of sport fish could be expected to inhabit the area.

The advanced treatment plus additional flow augmentation option (plan A3) results in substantial improvements over existing conditions. During the worst year, dissolved oxygen conditions would fall into the "fair" range, and in the average year, "fair to good" conditions would exist and sport fish could be expected to inhabit the lower Speed river avoiding only a few sections.

While plan A3 provides the largest improvement in the water quality of the lower Speed river, it increases plan costs by $17 million. It also causes detrimental upstream environmental impacts such as the destruction of the cold-water fishery at the Everton reservoir site on the Eramosa river. With the creation of a reservoir, downstream water quality benefits in the lower Speed river are obtained at the expense of decreasing upstream water quality in the upper Eramosa river.

The option of providing advanced phosphorus treatment alone results in some improvement in water quality, particularly under worst year conditions.

As there has been no opportunity to assess the effects on water quality of the newly installed rotating biological contactors for nitrification at the Guelph sewage treatment plant, no decision on additional treatment should be made until an adequate amount of field data has been collected and the benefits of the RBCs assessed. Then, additional treatment and other remedial measures such as instream aeration or aquatic plant removal should be evaluated further.

Variation of Water Quality With Population Projections

The dissolved oxygen conditions in the central Grand river and the Speed river are relatively independent of population growth except for the Speed river during average year conditions. For example, the Grand river water quality index for the conventional treatment option changes only 11 percent by the year 2001 while the population doubles in size (Fig. 10.6). This means that the dissolved oxygen levels are already dominated by maximum biomass conditions as well as oxygen-demanding loads, and additional nutrients from sewage flows would cause little additional biomass growth. Consequently, dissolved oxygen levels in the central Grand river would decrease only slightly with an increasing population. In contrast, because of unusual hydraulic conditions the dissolved oxygen levels in some reaches of the Speed river may increase slightly during average year conditions because of increased sewage flows from urban growth and the high level of treatment provided at Guelph.

10.3 Provide Adequate Water Supplies

Municipal Needs

The main area where municipal water demands will outstrip available supplies is in the Regional Municipality of Waterloo. Existing municipal ground water supplies will have to be supplemented by additional surface water abstraction, either from the Grand river (plans A, B and C) or from a lake source (plan D). Although the water supply projects incorporated in the four plans will meet 100 percent of future average and maximum day demands, there is a wide disparity in water supply costs and benefits. For example, the water supply costs of plan D, which utilizes the Lake Erie pipeline for water supply, are 20 times more than those of plan A, B or C. In addition, the benefits derived would be less than the costs.

Variation in Future Municipal Water Demand

The staging and costs of water supply projects will depend directly on the growth rate of municipalities and the application of water conservation methods. For example, a low population growth rate in the Cities of Kitchener, Waterloo and Cambridge could delay the necessity of implementing phase II of the Mannheim recharge scheme by approximately five years. A low population growth rate combined with a reduction in water demand of 5 percent for the average day and 10 percent for the maximum day could delay the necessity of implementing phase I of the Mannheim recharge scheme by five years, and phase II by fifteen years. The implementation of new ground water sources for Cambridge could be delayed by ten years (Ref. Tech. Report No. 26).

Industrial Needs Independent of Municipal Use

Unless the municipal ground water supplies are adequately protected in the central Grand river basin, projections indicate that separate industrial ground water abstractions may compete with municipal ground water supplies (Sec. 6.1.4). At present, the Regional Municipality of Waterloo limits the amount of ground water new manufacturing firms may abstract and the City of Guelph requires new factories to use existing municipal supplies. As long as such restrictions continue and there are no large expansions in demands from existing users, adequate ground water supplies will be available in the central basin to meet industrial needs independent of municipal use.

For the remainder of the basin, projections indicate that separate industrial water demand should be met adequately by existing sources, principally by surface water.

Agricultural Needs

A preliminary analysis by the basin study indicates that there is generally an adequate supply of water for irrigation purposes in sandy and sandy loam areas for future needs. It was assumed that the crops grown on heavy clay will not need irrigation. More detailed studies are required to determine the economics of irrigating such crops as corn and the feasibility of matching individual irrigation requirements with supply.

10.4 Summary of Plan Costs and Benefits

The dollar value of costs and benefits for each of the four main plans is summarized in Table 10.3. Each plan's effectiveness in achieving the three basin study objectives is indicated by a percentage of the objective achieved. The objectives used to evaluate plan effectiveness are: for flood damage reduction reduce average annual damages to zero; for water supply meet maximum day demands; and for water quality meet a water quality index of 0.

The monetary value of benefits has been calculated for flood protection and water supply projects, but because of the difficulty in estimating the monetary value of such water quality benefits as aesthetics, improved aquatic life, and public health, the dollar value of water quality benefits has not been calculated (Appendix C). Costs include all components of the plan except the cost of expanding the existing sewage treatment plants. The expansion costs were not included in the comparison with benefits because it is the new additional treatment facilities which contribute to the improved water quality, rather than the expansions of existing sewage treatment processes which maintain the status quo by preventing further degradation.

The dollar value of costs and benefits presented in Table 10.3 has been calculated based on a medium population projection and is compared with other population projections in Figure 10.11. This figure shows that for various projections, costs vary less than benefits. This is mainly due to the large water supply (consumer surplus) benefits derived from the high populations for a relatively small increase in costs.

Plans A1, A2 and A4, involving dyking and channelization, local sources of water supply and advanced sewage treatment, have the highest net benefits and plan D, the pipeline plan, has the lowest net benefits. This ranking is maintained for other discount rates ranging from 0 to 10 percent.

Table 10.3 SUMMARY TABLE OF COSTS AND BENEFITS FOR MAIN PLANS — MEDIUM POPULATION PROJECTION

(Millions of 1979 Dollars)

	PLAN DESCRIPTION:			PRESENT VALUE OF BENEFITS & COSTS			
				DISCOUNT RATE			
PLAN	WATER QUALITY	WATER SUPPLY	FLOOD DAMAGE REDUCTION	ITEM	0%	6%	10%
A Option 1	Sewage Treatment: Kitchener - Nitrification Filtration 1981 Waterloo - Nitrification Filtration 2001 Guelph - Chemical Treatment and Multi-Media Filtration 1981 28% - Speed 23% - Grand	Ground Water: Cambridge, Guelph Surface Water: Kitchener-Waterloo 1991 Cambridge connect to Kitchener-Waterloo 2021 100%	Dykes & Channel Works in: Preston, Galt, Paris, Brantford, Caledonia, Dunnville, New Hamburg 91%	1) STP-CAS + Guelph RBC	379	94	54
				2) STP-New Facilities	77	30	23
				3) Water Supply	38	14	9
				4) Reservoirs	0	0	0
				5) Other Flood Prot.	25	24	23
				6) Water Sup. Benefits	1078	107	26
				7) Flood Prot. Benefits	46	14	9
				8) Net Benefits = (6 + 7) - (2 + 3 + 4 + 5)	984	53	-20
A Option 2	Same as Plan A Option 1 28% - Speed 23% - Grand	Ground Water: Cambridge, Guelph Surface Water: Kitchener-Waterloo 1991 Cambridge connect to Kitchener-Waterloo 1986 100%	Same as Plan A Option 1 91%	1) STP-CAS + Guelph RBC	379	94	54
				2) STP-New Facilities	77	30	23
				3) Water Supply	34	13	8
				4) Reservoirs	0	0	0
				5) Other Flood Prot.	25	24	23
				6) Water Sup. Benefits	1074	107	26
				7) Flood Prot. Benefits	46	14	9
				8) Net Benefits = (6 + 7) - (2 + 3 + 4 + 5)	984	54	19
A Option 3	Same as Plan A Option 1 Flow Augmentation on Speed River from Everton Reservoir 69% - Speed 23% - Grand	Same as Plan A Option 1 100%	Same as Plan A Option 1 91%	1) STP-CAS + Guelph RBC	379	94	54
				2) STP-New Facilities	77	30	23
				3) Water Supply	38	14	9
				4) Reservoirs	17	16	15
				5) Other Flood Prot.	25	24	23
				6) Water Sup. Benefits	1078	107	26
				7) Flood Prot. Benefits	46	14	9
				8) Net Benefits = (6 + 7) - (2 + 3 + 4 + 5)	967	37	35
A Option 4	Same as Plan A Option 1 Possible future augmentation on Grand River from Montrose Reservoir 28% - Speed 23% - Grand	Same as Plan A Option 1 100%	Same as Plan A Option 1 Acquire Montrose Reservoir land for possible future use 91%	1) STP-CAS + Guelph RBC	379	94	54
				2) STP-New Facilities	77	30	23
				3) Water Supply	38	14	9
				4) Reservoir Land	0*	4*	5*
				5) Other Flood Prot.	25	24	23
				6) Water Sup. Benefits	1078	107	26
				7) Flood Prot. Benefits	46	14	9
				8) Net Benefits = (6 + 7) - (2 + 3 + 4 + 5)	984	49	25

Note: Percent figures refer to % of objective achieved, except where noted the objectives are: Water Quality — meet a water quality index of 0.0 on the Grand river and on the Speed river. Water Supply — Max. Day Demand. Flood Damage Reduction — zero average annual damages.

* For purposes of economic analysis it was assumed that the land acquired for the Montrose reservoir would be sold in the year 2001.

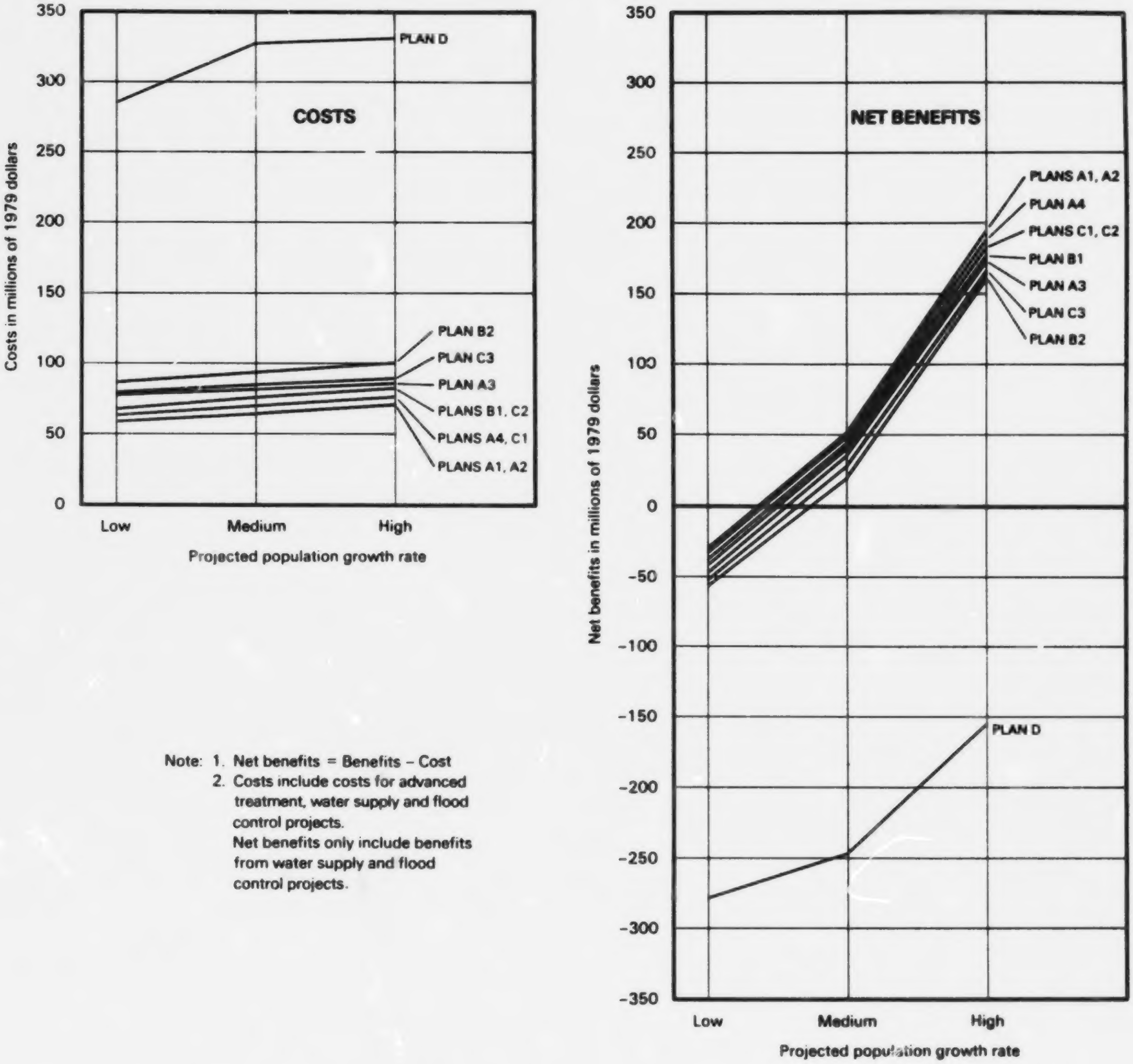
Table 10.3 SUMMARY TABLE OF COSTS AND BENEFITS FOR MAIN PLANS — MEDIUM POPULATION PROJECTION (Continued)
(Millions of 1979 Dollars)

PLAN	PLAN DESCRIPTION			PRESENT VALUE OF BENEFITS & COSTS			
	WATER QUALITY	WATER SUPPLY	FLOOD DAMAGE REDUCTION	ITEM	DISCOUNT RATE		
					0%	6%	10%
B Option 1	Sewage Treatment Kitchener – Nitrification Filtration 2001 Waterloo – Nitrification Filtration 2021 Guelph – Chemical Treatment and Multi-Media Filtration 1981 Flow Augmentation Montrose Reservoir 28% Speed 58% Grand	Same as Plan A Option 1 100%	Montrose Reservoir Dykes in New Hamburg 54% 56%	1) STP-CAS + Guelph RBC	379	94	54
				2) STP-New Facilities	68	17	10
				3) Water Supply	38	14	9
				4) Reservoirs	46	42	41
				5) Other Flood Prot.	1	1	1
				6) Water Sup. Benefits	1078	107	26
				7) Flood Prot. Benefits	27/28*	9	5
				8) Net Benefits = (6 + 7) − (2 + 3 + 4 + 5)	952/ 953	42	-30
B Option 2	Same as Plan B Option 1 28% Speed 58% Grand	Same as Plan A Option 1 100%	Montrose Reservoir Dykes and Channel Works same as Plan A, Option 1 96%	1) STP-CAS + Guelph RBC	379	94	54
				2) STP-New Facilities	68	17	10
				3) Water Supply	38	14	9
				4) Reservoirs	46	42	41
				5) Other Flood Prot.	25	24	23
				6) Water Sup. Benefits	1078	107	26
				7) Flood Prot. Benefits	48	15	9
				8) Net Benefits = (6 + 7) − (2 + 3 + 4 + 5)	949	25	-48
C Option 1	Same as Plan A Option 1 28% Speed 23% Grand	Same as Plan A Option 1 100%	St. Jacobs Dry Reservoir Dykes in New Hamburg 49% 50%	1) STP-CAS + Guelph RBC	379	94	54
				2) STP-New Facilities	77	30	23
				3) Water Supply	38	14	9
				4) Reservoirs	26	25	24
				5) Other Flood Prot.	1	1	1
				6) Water Sup. Benefits	1078	107	26
				7) Flood Prot. Benefits	25/26*	8	5
				8) Net Benefits = (6 + 7) − (2 + 3 + 4 + 5)	961/ 962	45	26
C Option	Same as Plan A Option 1 28% Speed 23% Grand	Same as Plan A Option 1 100%	Montrose Dry Reservoir 24.7 million cubic metres (20 000 acre feet) Dykes in New Hamburg 54% 56%	1) STP-CAS + Guelph RBC	379	94	54
				2) STP-New Facilities	77	30	23
				3) Water Supply	38	14	9
				4) Reservoirs	30	28	27
				5) Other Flood Prot.	1	1	1
				6) Water Sup. Benefits	1078	107	26
				7) Flood Prot. Benefits	27/28*	9	5
				8) Net Benefits = (6 + 7) − (2 + 3 + 4 + 5)	959/ 960	43	29
C Option 3	Same as Plan A Option 1 28% Speed 23% Grand	Same as Plan A Option 1 100%	Montrose Dry Reservoir 77.7 million cubic metres (63 000 acre feet) Dykes in New Hamburg 56% 57%	1) STP-CAS + Guelph RBC	379	94	54
				2) STP-New Facilities	77	30	23
				3) Water Supply	38	14	9
				4) Reservoirs	46	42	41
				5) Other Flood Prot.	1	1	1
				6) Water Sup. Benefits	1078	107	26
				7) Flood Prot. Benefits	27/28*	9	5
				8) Net Benefits = (6 + 7) − (2 + 3 + 4 + 5)	943/ 944	29	43
D	Same as Plan A Option 1 28% Speed 23% Grand	Lake Erie Pipeline Kitchener-Waterloo Cambridge, Brantford Ground Water Guelph 100%	Same as Plan A 91%	1) STP-CAS + Guelph RBC	348	89	52
				2) STP-New Facilities	75	29	22
				3) Water Supply	553	278	230
				4) Reservoirs	0	0	0
				5) Other Flood Prot.	25	24	23
				6) Water Sup. Benefits	825	66	9
				7) Flood Prot. Benefits	46	14	9
				8) Net Benefits = (6 + 7) − (2 + 3 + 4 + 5)**	218	-251	-257

Note: Percent figures refer to % of objective achieved; except where noted the objectives are: Water Quality – meet a water quality index of 0.0 on the Grand river and on the Speed river. Water Supply – Max. Day Demand. Flood Damage Reduction – zero average annual damages.

* A range of flood damage benefits is given for multi-purpose reservoirs. This range reflects variations in the assumed storage volume available in the spring to retain flood flows. Storage volumes will vary with the time of year and the operating rules used for each reservoir.

** Net benefits include savings in cost item 1 over Plan A. These savings arise due to a reduced STP hydraulic load brought about by price induced reductions in water demand.



Note: 1. Net benefits = Benefits – Cost
2. Costs include costs for advanced treatment, water supply and flood control projects.
Net benefits only include benefits from water supply and flood control projects.

Figure 10.11. Present value of costs and net benefits of main plans versus population projections. (millions of 1979 dollars at 6% discount).

10.5 Uncertainty

As the impacts of a project or plan are estimated over a considerable time into the future, there is no guarantee that the project effects will exactly meet the predictions. Although there may be little doubt that the immediate effects will occur as projected, the degree of doubt or uncertainty increases the further into the future projections are made.

This study has grouped uncertainties into two types, one dealing with input to the plan such as population projections and flow forecasts and the second dealing with plan performance such as possible failure of dykes and dams and reliability of water supply options. Where uncertainties can be defined by probability, the uncertainty is often called a risk.

Some of the more important uncertainties involved in achieving each objective are discussed in the following sections.

10.5.1 Uncertainty In Reducing Flood Damages

Uncertainty in reducing flood damages can be divided into two classifications: (1) uncertainty in predicting such quantities as flood damages, flood flows and flood frequencies; and (2) risk of not achieving flood damage objectives through project failure.

Prediction Uncertainty

Estimates of future annual flood damages can be affected by floodplain development, changes in the frequency or magnitude of floods, and risks of structural failure. A review of past floodplain development trends indicates that the total annual damages for the basin will not vary significantly in the future, due to floodplain development. However, the damages for small local areas such as New Hamburg could vary widely (Sec. 10.1; and Appendix F).

Recent studies have indicated that in Cambridge (Galt) flood volumes have increased 18 percent and the frequency of flood occurrences has more than doubled in the last forty years (Ref. 1).

While it is suspected that increases in row cropping and artificial drainage have increased natural flood flows, there is no conclusive proof to this effect. Furthermore, it is uncertain whether the trend to increasing flood flows has peaked or will continue.

Low frequency floods such as the 50-year or 100-year floods, have been predicted using short term rainfall and streamflow records having a period of record less than twenty-five years. The extrapolation of short term records many years into the future can introduce error into the calculation of flood flows and flood damage.

For example, there is a 5 percent risk that the 100-year flood, instead of being 1,634 m^3/s at Cambridge (Galt) could be as high as 2,274 m^3/s or as low as 994 m^3/s. Similarly, the average annual damages could vary from $1,500,000 to $47,000 (Table 10.4).

Plan Uncertainty

While the dykes and channelization of plan A offer the most flood damage reduction at the least cost, they have a higher risk of failure than a dam.

Because of economics, dykes are usually built to withstand a smaller flood than a dam and hence the risk of failure is higher. Major dykes are currently designed to allow safe passage of the flood created by a regional storm while modern dam spillways are built to withstand a flood flow of approximately double this size without damaging the dam itself (although flooding downstream is not prevented). In addition to overtopping by flood waters, dykes can fail from operational or structural causes. Until recently, almost every dyke constructed on the Grand river failed because the dyke system was not completed or was overtopped (Table 10.5). Incomplete dyke systems were the result of lack of funds or shifting priorities as the memory of the latest flood disaster receded into the past. Operational failures can occur if openings in the dyke system such as bridge entrances or drain outlets are not blocked. For example, flood damages will occur behind the Cambridge (Galt) dyke system if the entrances to the bridges crossing the Grand river are not closed during periods of severe flooding.

Table 10.4 Flood Flows, Frequencies and Damages at Cambridge (Galt)

	Return Period in Years			Average Annual Damages
	20	50	100	
1) Upper 95% confidence limit	1,529 m^3/s	1,926 m^3/s	2,274 m^3/s	$1,500,000
2) Best estimate	1,189 m^3/s	1,416 m^3/s	1,634 m^3/s	$ 490,000
3) Lower 95% confidence limit	849 m^3/s	906 m^3/s	994 m^3/s	$ 47,000

Table 10.5 Dyke Failures for Selected Flood Damage Centres Within the Grand River Basin

Municipality	Date/Period of Installation	Date of Failure	Reason for Failure		
			Insufficient Height	Insufficient Length	Breached
Brantford*	1887-1937	1929	x	x	x
		1932	x	x	x
		1948	x	x	x
	1949	1950	x	x	x
		1954	x	x	x
		1974	x	x	x
	1980				
New Hamburg	1954	1954	x	x	
	1970	1974	x	x	
		1975	x	x	
Kitchener-Bridgeport	1956		x	x	x
	1957				
	1959	1974			
Paris	1928	1929	x	x	
		1932	x	x	
		1947	x	x	x
	1947	1974	x	x	
	1957	1975	x	x	
	1975	1979	x	x	

* Brantford has installed over 5 1/2 miles of dykes since 1887; all three reasons accounted for dyke failure during floods.

To avoid similar problems, the dykes proposed in plans A to D will utilize modern construction techniques and will be designed to withstand the regional flood. However, the high performance of these dyking projects will be achieved only if the dyking systems are completed and operated efficiently.

10.5.2 Uncertainty In Maintaining Adequate Water Supply

Uncertainty in achieving an adequate water supply can be divided into two categories: (1) uncertainty in predicting water supply demands because of variations in population and water conservation forecasts; and (2) the uncertainty of not meeting water supply demands because of supply shortages or water quality problems.

Prediction Uncertainty

Future water demands are highly dependent upon population projections and the effects of water conservation. To capture this uncertainty, the basin study considered three and, in some cases, four population projections as well as varying rates of water conservation.

For plans A, B and C, supply costs based on a medium population projection are increased by $3 million for a high population projection and decreased by $2.5 million for a low population projection (present value of costs counted at 6 percent). This is relatively insignificant compared to plan D where medium population projection supply costs discounted at 6 percent, are increased $6 million for a high population projection and decreased by $40 million for a low population projection.

Plan Uncertainty

In plans A, B and C, the future water supply for Kitchener-Waterloo depends upon withdrawing water from the Grand river by infiltration wells and direct pumping to recharge areas.

Three questions arise from these water supply projects. First, is there a sufficient supply of water available to meet future demands? Second, is the water quality suitable for a drinking water supply? Third, is the Mannheim recharge system feasible?

Hydraulic simulations were carried out to determine the reliability of plans A, B and C in meeting a variety of target flows at two river locations — Kitchener and Brantford (Sec. 9.5). Table 10.6 shows the maximum river flow requirements for the Mannheim scheme to supply water to Kitchener-Waterloo. Future river withdrawals could be met if the existing reservoirs were operated to achieve a minimum supply rate of 3.8 m^3/s (plans A, C and D, Table 9.4). However, at present the existing reservoirs are not operated to meet a specific target flow during the winter months. The existing operating policy would have to be modified to include winter target flows to ensure adequate winter water supply (Sec. 9.5.).

Table 10.6 Maximum River Flow Requirements for Water Supply to Kitchener-Waterloo Option 1, Plans A-C

Population Projection		Grand River Withdrawals in m^3/s near Kitchener-Doon	Comments
2001	High	0.45	River withdrawals are used to supply infiltration wells and Mannheim recharge scheme.
	Medium	0.40	
	Low	0.003	
2031	High	1.61	
	Medium	1.19	
	Low	0.45	

An uncertainty of some concern that is not completely addressed by the study is the possibility of contamination of the water supply from upstream sources of synthetic organic compounds and the creation of organic compounds during the disinfection process at Mannheim prior to distribution.

Based on the information available to date, the chief sources of upstream industrial organics appear to be from current and past operations of the Uniroyal Ltd. chemical complex at Elmira (Sec. 6.4.2) and from an abandoned industrial waste landfill site at Breslau near Kitchener. Upstream sewage treatment plants, most notably the Waterloo plant, may also be contributing organic compounds. These sources are located above the intake of the Mannheim recharge scheme and the Woolner Flats induced infiltration site. The Forwell induced infiltration site is upstream from the Breslau site but downstream from Elmira.

At Elmira, industrial wastes are pre-treated by Uniroyal Ltd. and then discharged to the Elmira sewage treatment plant for further treatment. Some organic compounds have been detected in the effluent from the treated sewage treatment plant and in downstream reaches of Canagagigue creek, but, at this time, their significance with respect to downstream water supply does not appear to be serious.

A new industrial waste treatment process is currently being installed at Uniroyal Ltd. The impact of this process on influent and effluent quality at the sewage treatment plant will have to be carefully assessed.

In addition, there is some initial evidence that industrial organic compounds may be leaching from Uniroyal's abandoned waste disposal sites. Preliminary surface and subsurface investigations indicate that the concentrations of any monitored organic chemicals reaching Canagagigue creek are well below drinking water objectives (Ref. 15) by the time the creek reaches the main Grand river and organic chemicals have not been detected in adjacent ground water supply wells at Elmira. The operations at the industry are under continuing surveillance by the Ministry of the Environment, Environment Canada and Uniroyal to determine if further improvements in waste treatment or management are needed.

At Breslube Enterprises near Kitchener, high levels of phenolic compounds have been detected in drains from the abandoned waste disposal site. Detailed investigations are being carried out by the Ministry of the Environment and the Regional Municipality of Waterloo to determine the best method of controlling this contamination and stopping any discharge to the river.

Preliminary sampling for industrial organic compounds at twelve sites on the Grand river and its tributaries have indicated that industrial organics in low concentrations are present in the river. However, based on available drinking water objectives, (Ref. 15) the river water is suitable for municipal water supply. As the initial investigations were preliminary in nature, a much more extensive water sampling program must be carried out prior to instituting the Mannheim water supply scheme. The program is also necessary for evaluating the induced infiltration sites at Kitchener and other downstream withdrawal sites at Brantford and Cayuga. A suggested source-identification-surveillance program is included in Appendix E.

The third uncertainty with respect to the water supply projects centres on the feasibility of the Mannheim recharge scheme. Preliminary ground water investigations carried out by the Regional Municipality of Waterloo indicate that the Mannheim recharge scheme is feasible. However, further testing is necessary to complete the investigation. If this scheme is unable to supply an adequate amount of water to Kitchener-Waterloo, other alternatives such as plan B, the Montrose reservoir option, would have to be reconsidered.

10.5.3 Uncertainty In Maintaining Adequate Water Quality

In dealing with water quality, an important question to examine is: what is the uncertainty involved in predicting future water quality conditions This will involve uncertainties in population predictions, in sewage treatment plants not meeting specified effluent standards, and in the accuracy of the water quality simulation model. If it can be assumed that the predicted water quality results are reasonably accurate, a second question arises: how often do the various plans meet the water quality objectives?

Prediction Uncertainty

While water quality benefits for all four management plans do not change significantly with population increases (Sec. 10.3) the costs of treatment will vary with increases in population.

The sewage treatment costs calculated for the medium population projection will be increased by approximately $25 million for a high population projection and decreased by approximately $20 million for a low population projection.

The probability of existing sewage treatment plants not meeting their specified effluent standards was determined by obtaining the probability distribution of actual effluent characteristics and incorporating it into the water quality model.

As most of the differences in water quality between plan A and plan B were measured by a complex mathematical water quality model, it was necessary to determine how precisely this difference was simulated. The model was calibrated on one year of observed data and then tested and verified on a different year of observed data. At any point in time, the accuracy of the simulated dissolved oxygen concentrations was ± 1 mg/L when compared with observed results. When compared to observed data, the model accurately reproduced the number of times that the dissolved oxygen value fell within the critical range of 2 to 4 mg/L, 99.6 percent of the time.

While the accuracy of modelling existing conditions is good, the accuracy of predicting future water quality conditions with substantially different loadings and hydraulic conditions remains uncertain.

Another uncertainty is predicting the occurrence and effect of accidental chemical spills such as those which occur as a result of train derailments upon surface and ground water quality. Such spills can affect aquatic life and sources of water supply. Generally, the effects of such spills are of a short term nature in surface waters and the effects on water supplies can be reduced by adequate warnings and containment procedures. However, spills that affect ground water resources can have a long term effect and abatement is extremely difficult. At present, the Ministry of the Environment, working with other appropriate agencies, has a contingency program to ensure a rapid response to such emergencies with effective mitigation procedures to minimize environmental damage and risk to human health and safety.

Plan Uncertainty

An estimate of how well each plan fulfills the dissolved oxygen objective of 4 mg/L is given by the percent time each plan meets the objective for average year and worst year conditions. For example, under average year conditions in 2001 at reach 5 on the Grand river (the most seriously degraded reach in terms of dissolved oxygen), existing conventional treatment will meet or exceed the objective only 57 percent of the time during the month of August, plans A, C and D will meet the objective 80 percent of the time and plan B will meet the objective 98 percent of the time. Similarly, during the worst year or the one-in-twenty year occurrence, in the year 2001 at reach 5, existing conventional treatment will meet the objective 40 percent of the time, plans A, C and D will meet the objective 55 percent of the time, and plan B will meet the objective 93 percent of the time.

Of course, the percent time when conditions meet the objective will increase and vary in other reaches as noted in Section 10.3 and Figure 10.3.

Summary

From the discussion regarding risks and uncertainties, it can be concluded that the selected water resource plan should be sufficiently flexible in design to deal with future risks and uncertainties. The two most flexible water management plans are plan A4 and plan B. Both plans provide for the opportunity of developing an alternative water supply source by using the water from a reservoir at Montrose. Plan A4 maintains the option of obtaining a higher water quality through increased flow augmentation in the central Grand river if this is required in future years.

11. COMPARISON AND EVALUATION OF MAIN PLANS

The four plans and the related options which were selected for further consideration (Table 11.1; and Fig. 11.1) were compared and evaluated by technical members of the basin study team, water managers from the major municipalities in the basin, and four public consultation working groups. These evaluations were considered by the Grand River Implementation Committee (GRIC) in their identification of a preferred plan.

11.1 Comparison of Plans

Comparisons of the four plans and their variations on the basis of costs, benefits, advantages and disadvantages are summarized in Table 11.1. Briefly, plans A1 and A2 are the most economical plans with minimal overall environmental and social impacts. Plan A3, which utilizes a dam at Everton to obtain a higher water quality on the lower Speed river, was discarded by the technical and public groups since high environmental impacts would be incurred at the reservoir site offsetting the benefits which would be accrued further downstream. Plan A4 provides the most flexibility because the Montrose reservoir site would be preserved until future risks and uncertainties are identified or dispelled.

Plan B1, utilizing the Montrose reservoir but not dyking and channelization, was unanimously rejected by the technical and public groups because it did not adequately meet the objective to reduce flood damages and would cause significant detrimental social and environmental impacts. Plan B2, which includes dyking and channelization along with the Montrose reservoir, is the most reliable plan as it gives additional flood protection and increased water quality (Fig.11.1). However, it costs $29 million dollars more than Plan A1 and the negative environmental and social impacts are greater.

Plan C, the dry or single-purpose reservoir option, is a compromise between the no reservoir plans (plan A1, A2 and D) and the multi-purpose reservoir option (plan B). This plan reduces the detrimental environmental impacts of a reservoir but provides less flood protection than plan A1 and less water quality improvement than plan B. In addition, the dry reservoir option produces many of the same negative social impacts as does the multipurpose reservoir option. Therefore, plan C was also rejected by the technical and public groups.

Plan D, the Lake Erie pipeline plan, while having minimal longterm environmental and social impacts, is the most expensive plan with high water supply operational costs of over $5 million per year. Because this plan is over five times more expensive than plan A and the other less expensive plans can adequately meet the study objectives, it was rejected by the technical and public groups.

11.2 Evaluation of Plans By Technical Groups

The technical staff of the basin study selected plans A1, A2, A4 and B2 as being the best plans but preferred plan A4 over the others.

In contrast, the water managers who are charged with the day-to-day responsibility of operating major flood control, water supply and sewage treatment services preferred plan B2 because it offered, in their opinion, a more reliable and secure water management system.

PUBLIC WORKING GROUP: These citizen advisory groups aided the study in evaluating the various water management plans

11.3 Evaluation of Plans By Public Groups

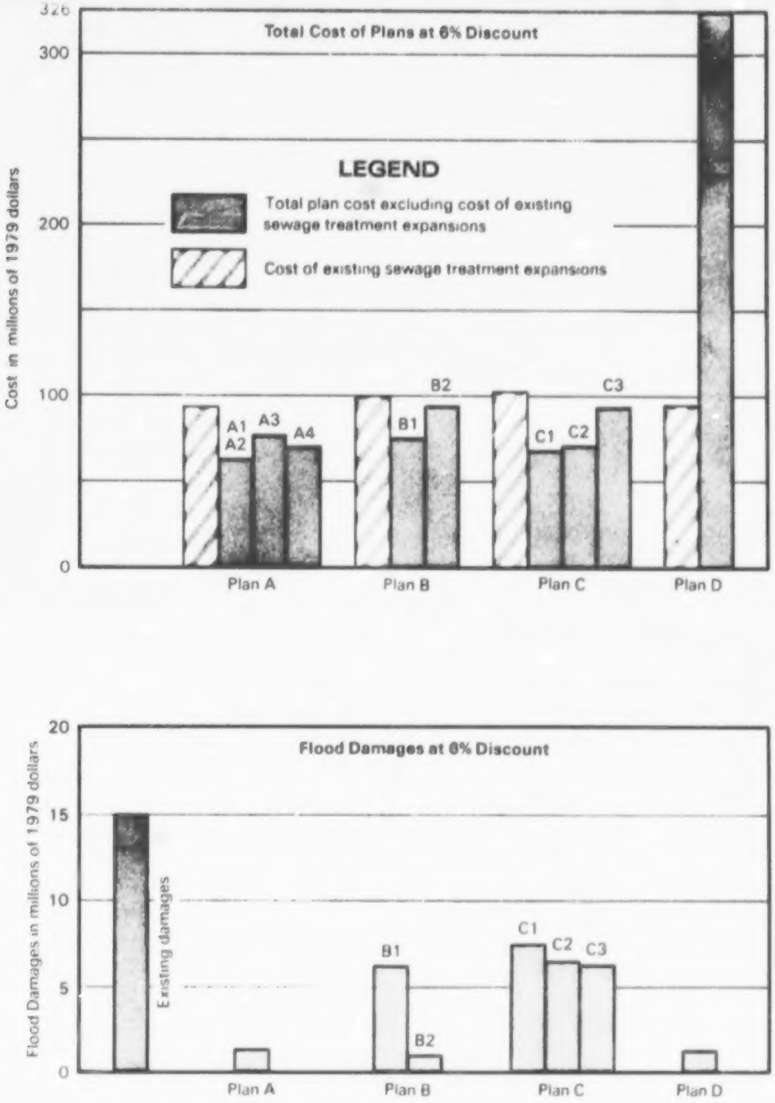
The evaluation by representatives of the public was carried out by four public consultation working groups made up of citizens from different geographical areas of the basin. Three of the four working groups selected plans A1 and A2 as the preferred plans. The fourth group, representing the lower portion of the basin preferred plan B2, the Montrose reservoir option, because of its greater ability to reduce flood flows, maintain higher summer flows and improve water quality.

The working groups tended to favour the plans with minimal social impacts. Two of the three public groups selecting plans A1 and A2 were opposed to plan A4.

TABLE 11.1 COMPARISON OF MAIN PLANS — MEDIUM POPULATION PROJECTION

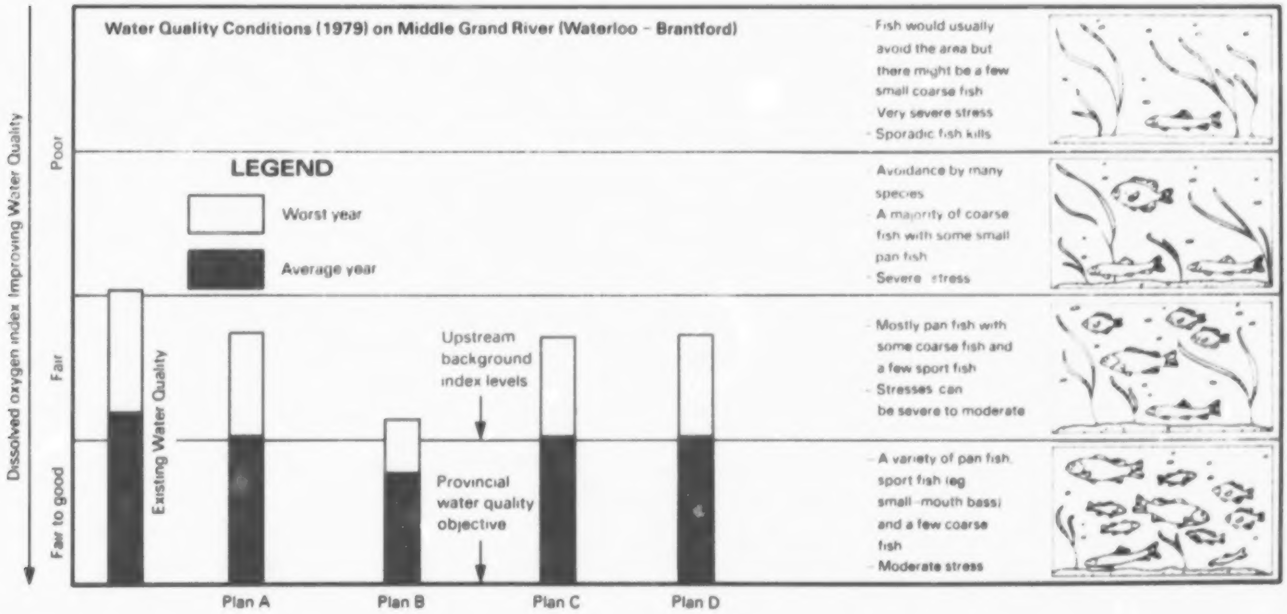
Plan	Costs	Benefits	Advantages	Disadvantages
	Present value at 6%, millions of 1979 dollars			
Plan A1, A2 • Dyking and channelization at New Hamburg, Cambridge (Galt and Preston), Paris, Brantford, Caledonia and Dunnville • Advanced sewage treatment for Kitchener, Waterloo and Guelph • Local sources of water supply Plan A1 - new ground water supplies for Cambridge Plan A2 - new water supply to Cambridge via Mannheim recharge system	68* 66*	121 121	1. Lowest cost solution. 2. Minimal environmental and social impacts, localized to dyking and channelization sites. 3. Water quality on Grand and Speed rivers generally is improved, but does not meet MOE D.O. objective fully near Kitchener and Guelph. 4. Provides urban flood protection against floods greater than 100-year flood at sites with dyke protection (91% reduction in flood damages). 5. Meets water supply needs. 6. Socially most acceptable as reflected by Public Consultation Working Groups.	1. Lower water quality on Grand river (Waterloo to Paris) than B1, B2. 2. No additional flood protection for areas not provided with dykes. 3. Flood damage reduction provided only if dyke projects are carefully planned and co-ordinated.
Plan A3 • Same as A1 plus Everton reservoir on Speed river	84*	121	1. Flood protection and water supply same as A1. 2. Water quality on Speed river below Guelph is better than A1, but still does not meet MOE D.O. objective fully.	1-3. Same as A1. 4. Has detrimental impact on cold water fishery in reservoir site. 5. Reservoir increases A1 costs by $16 M.
Plan A4 • Same as A1 plus appropriate measures to be taken to preserve the Montrose reservoir site for possible future use	72* (Montrose lands disposed of in 2001) 83* (Reservoir constructed in 2001)	121 121	1. Water quality, flood protection and water supply same as A1. 2. Minimal environmental impacts (unless dam is constructed in the future). 3. Gradual social impacts during land acquisition. 4. Flexibility to handle future water quality uncertainties is increased. 5. Permits continued agricultural use of lands in reservoir acquisition area.	1-3. Same as A1. 4. Does not eliminate uncertainty about future land use. 5. No assurance that land-use planning can preserve the reservoir site except through provincially imposed regulations or purchase. 6. $4 M more costly than A1 if the reservoir is not built and $15 M more costly if the reservoir is built.
Plan B1 • Montrose dam • Advanced sewage treatment at Kitchener and Guelph • Local sources of water supply same as A1	74*	116	1. Water quality on Grand and Speed rivers is improved over Plan A, but still does not meet MOE D.O. objectives fully near Kitchener and Guelph. 2. Provides flood protection against a 10-year flood. 3. Provides additional flood protection for rural areas. 4. Meets water supply needs with greater flexibility for possible future needs. 5. Reservoir provides additional recreational opportunities.	1. Costs $6 M more than A1. 2. Has detrimental social and environmental impacts. 3. Provides less flood protection than A1. 4. Has considerable local opposition.
Plan B2 • Montrose dam • Dyking and channelization same as A1 • Advanced sewage treatment at Kitchener and Guelph • Local sources of water supply same as A1	97*	122	1. Same as B1. 2. Provides urban flood protection against floods greater than a 100-year flood (96% reduction in flood damages) as A1. 3. Reduces the risk of dyke failure by reducing flood peaks. 4. Provides added protection if future flood flows increase due to changing land-use practices. 5. Provides additional flood protection for rural areas. 6. Meets water supply needs with greater flexibility for possible future needs. 7. Reservoir provides additional recreational activities.	1. Costs $29 M more than A1. 2. Has detrimental social and environmental impacts. 3. Has considerable local opposition.
Plan C1 • St. Jacobs dry reservoir with dyking and channelization at New Hamburg • Advanced sewage treatment same as A1	70*	115	1. Less environmental impact than Montrose dam. 2. Provides urban flood protection against a 10-year flood and reduces flood damage by 50-49%. 3. Water quality on the Grand and Speed rivers improved, but does not meet MOE D.O. objective fully near Kitchener and Guelph. 4. Meets water supply needs. 5. $27 M less costly than B2.	1. Has detrimental social impact. 2. Provides less urban flood protection than A1, A2, B1 and B2. 3. $2 M more costly than A1.
Plan C2 • Montrose small dry reservoir, 24.7 million cubic metres (20,000 acre-ft) with dyking and channelization at New Hamburg • Advanced sewage treatment same as A1 • Local sources of water supply same as A1	73*	116	1-4. Same as C1. 5. $24 M less costly than B2. 6. Reduces flood damages by 56-54%.	1-3. Same as C1. 4. $5 M more costly than A1.
Plan C3 • Montrose large dry reservoir 77.7 million cubic metres (63,000 acre-ft) with dyking and channelization at New Hamburg • Advanced sewage treatment same as A1 • Local sources of water supply same as A1	87*	116	1-4. Same as C1. 5. $10 M less costly than B2. 6. Reduces flood damages by 57-56%.	1-3. Same as C1. 4. $19 M more costly than A1.
Plan D • Pipeline from Lake Erie • Dyking and channelization same as A1 • Advanced sewage treatment same as A1	331**	80	1. A secure source of water supply (water supply needs are met). 2. Provides urban flood protection against floods greater than a 100-year flood at sites with dyke protection (91% reduction in flood damages). 3. Water quality on the Grand and Speed rivers improved, but does not meet MOE D.O. objective fully near Kitchener and Guelph. 4. Services cities along the Grand river from one source with capacity limited only by design and cost considerations.	1. Highest cost plan. 2. Large short-term environmental impact along route. 3. High energy use for pumping - over $5 M annual operation costs. 4. Flood damage reduction provided only if dyke projects are carefully planned and co-ordinated.

* Costs listed do not include discounted cost of $94 M for conventional sewage treatment plant expansions.
** Costs listed do not include discounted cost of $89 M for conventional sewage treatment plant expansions.



Note - Options of plans are indicated by A1, A2
- Water quality is measured only by dissolved oxygen index. See chapter 6 and 10 for a more detailed discussion of other water quality parameters

Figure 11.1. Comparison of main plans for a medium population projection



12. THE PREFERRED PLAN

The following sections provide more detail on the major components of the preferred plan, plan A4, and describe various conservation and land use planning policies which will aid in meeting the water management objectives for the Grand river basin. Component costs and staging of the projects are included.

12.1 What The Plan Does

12.1.1 Reduce Flood Damages

In plan A4, a combination of structural and non-structural methods would be implemented or improved to reduce flood damages.

Structural Methods

Plan A4 reduces potential urban flood damages through the construction of dykes and channelization. In the urban centres of Cambridge (Galt and Preston), Brantford, Paris, Caledonia, New Hamburg, and Dunnville, damages would be reduced by 91 percent. They would be reduced by 90 percent in Grand Valley and by 95 percent in Plattsville on the Nith river.

Of the several structural, flood control alternatives investigated by the basin study, dykes and channelization provide the most cost-effective methods of reducing urban flood damages with minimum detrimental environmental and social impacts.

Another effective structural method of reducing flood damages is the flood proofing of homes and businesses situated in the floodplain. Flood proofing should be encouraged for:

(i) existing structures where dyke installation may not be practical because existing development already encroaches on river banks
(ii) new structures erected behind an existing dyke system.

Non-Structural Methods

While structural projects are useful in reducing flood damages, they do not guarantee immunity from floods at all places and at all times but only protect against floods of specified magnitudes. Since flood control structures do not completely eliminate the risk of flooding, further development in the floodplain after remedial control structures have been erected should be limited as outlined in the recently approved Grand River Conservation Authority (GRCA) policy which sets out stipulations for development on lands protected by major dyking projects.

The best tool in reducing or eliminating flood damages is regulating floodplain development. Present GRCA policies regulate development below the regulatory floodline (Ref. 16). These policies should be strengthened by the inclusion of a registered fill line along the river valleys. Municipalities should continue to develop and adopt policies in their official plans which would restrict the use of flood prone lands. Such policies should be implemented with the appropriate zoning by-law regulations and subdivision practices and should conform with GRCA and provincial floodplain management policies and regulations.

Where the flood hazard is severe and it is uneconomical to protect existing homes or businesses by dyking or flood proofing, the land and buildings could be acquired by the GRCA and/or by the municipality, although such measures are costly. Land acquisition will be necessary for dyking and channelization projects and, in some cases, additional land will be needed to reduce adverse impacts on adjacent property.

12.1.2 Provide Adequate Water Supply

In plan A4, water supply needs would be met through the use of local surface and ground water sources and the implementation of water conservation methods where warranted.

Local Sources For Major Urban Areas

Existing municipal ground water supplies for Kitchener-Waterloo will be supplemented by water withdrawn from the Grand river. These withdrawals will be accomplished by induced infiltration wells constructed near the river and by pumping from the river to recharge ground water at the Mannheim well field.

Additional water demand at Brantford will be met by further withdrawals from the Grand river. To meet future water needs, Guelph will continue to use municipal wells and a combined spring collection system and artificial recharge operation at Arkell. Elora and Fergus will have to develop additional ground water supplies by 2031. The potential for future ground water development for these two communities is good (Chapter 7; and Ref. Tech. Report No. 10).

Decrease Demand Through Water Conservation

Increasing water use, limits on the availability of large capacity ground water supplies in the central region of the basin, and the high cost of importing lake water are factors which emphasize the value of more efficient utilization of existing water supplies. For some areas, the adoption of water conservation methods could extend the life of the existing supplies and defer the need for new water supply and sewage treatment plants by approximately five to ten years.

Municipal consumption for the five major centres averages 541 L/capita•d (119 gpcd). With the adoption of various conservation programs, it is conceivable that an average per capita rate of consumption of approximately 414 L/capita•d (91 gpcd) can be obtained.

In order to reduce water demand, municipalities with limited supplies should consider moving from a decreasing rate structure as quantity used increases, to a constant rate as the City of Waterloo has done. Also, the introduction of a rate structure that includes a special summer surcharge would reduce excessive lawn sprinkling during the summer months, thereby reducing maximum day demand.

12.1.3 Provide Adequate Water Quality

In plan A4, water quality improvements would be made primarily by improved sewage treatment and wherever possible, by rural and urban non-point source controls. These water quality improvements would occur primarily in the central Grand river and in Lake Erie east of the river's mouth.

Sewage Treatment

Advanced sewage treatment facilities are required at Kitchener now to improve water quality in the Grand river. At the medium rate of population growth, advanced treatment would be needed at Waterloo by the year 2001. In addition, depending on the effectiveness of the newly installed facilities, advanced sewage treatment may be required at Guelph in the near future. Hydraulic expansions to the existing conventional sewage treatment facilities will be needed throughout the planning period. Major expansions would need to be carried out at Guelph in 1996, 2016 and 2031 and at Cambridge (Galt) in 2006 and 2021.

With plan A4, the provincial water quality objective for dissolved oxygen of 4.0 mg/L is achieved throughout most of the basin but it cannot be met fully at all locations, particularly in the central Grand and Speed rivers downstream from the major municipalities. The low dissolved oxygen levels (less than 2 mg/L), now common occurrences in both rivers, would be virtually eliminated in all but the worst year conditions. The addition of advanced sewage treatment facilities at Kitchener, Waterloo and Guelph also will reduce toxic wastewater loadings and the provincial water quality objective for ammonia will be met.

Several smaller urban areas have a local effect upon river water quality. At present, Elmira and Drayton require additional sewage treatment in order to meet the provincial water quality requirements. However, to accommodate future population growth, the communities of St. Jacobs, Elmira, Elora and Wellesley will be required to maintain the water quality objectives in the receiving streams (Chapter 7).

Rural Non-Point Source Controls

Rural non-point source controls should be concentrated in the Canagagigue, middle Grand, Conestogo and the Nith river sub-basins. These areas account for 80 percent of the sediment load, 70 percent of the phosphorus load and 70 percent of the nitrate-nitrite load in the whole Grand river basin.

A wide range of control measures are suggested, including: conservation tillage; fertilizer and manure management; buffer strips; and grassed waterways. The cost-effectiveness of each control measure will depend upon individual sites and will require detailed, site specific studies and evaluations. These measures will generally save the farmer time, soil, and fertilizer and will conserve the soil. They will aid in improving: Lake Erie water quality by reducing nutrient loadings; local stream quality by reducing bacteria concentrations; and to a lesser extent, depending upon the effectiveness of management practices, the nutrient and dissolved oxygen levels of the Nith and central Grand rivers.

Urban Non-Point Source Controls

While oxygen-demanding wastes in urban runoff do not materially affect the quality of the main Grand river or its tributaries, stormwater management practices should be applied wherever possible to protect the quality of small urban tributaries such as Schneider creek in Kitchener and Hanlon creek in Guelph (Ref. Tech. Report No. 26).

Urban stormwater practices such as street sweeping with vacuum pickups, catchment sump cleaning and the capture of sediment in storage ponds will reduce nutrient and heavy metal loadings to the local tributaries (Ref. Tech. Report No. 28).

12.2 How Much The Plan Costs

The capital, operating and maintenance costs of plan A4 are shown in five year increments (Table 12.1). The dates given are the approximate times when new facilities would be needed if populations increase at the medium projected growth rates. Similar tables have been developed for low and high population projections (Appendix C). Other rates of growth will accelerate or delay the times when some of the works are required.

At present, the GRCA owns about one-third of the 1,214 hectares (3,000 acres) required to protect the Montrose reservoir site. Much of the acquired land is still in agricultural use. The value of this land is $3.4 million.

Table 12.1 Water Management Plan A4 — Capital, Operating and Maintenance Costs Identified in Five-Year Increments Over the Fifty Year Planning Horizon Assuming Medium Population Growth

(costs are expressed in millions of dollars and are not discounted)

CAPITAL COSTS	1981	1986	1991	1996	2001	2006	2011	2016	2021	2026	2031	TOTAL COST
1. **Sewage Treatment**												
Region of Waterloo*	13.1				12.7	5.1			21.3	6.2	8.1	66.5
Guelph STP	4.7			21.3							21.3	47.3
Brantford STP										3.5	3.6	7.1
Total	17.8			21.3	12.7	5.1			21.3	9.7	33.0	120.9
2. **Channelization and Dyking**												
Region of Waterloo*	9.0											9.0
Brantford	6.8											6.8
Paris	5.5											5.5
Caledonia, Dunnville, New Hamburg	3.0											3.0
Total	24.3											24.3
3. **Water Supply**												
Region of Waterloo*		3.2	13.0		7.4							23.6
Guelph							0.5		0.2			0.7
Brantford				3.8								3.8
Total		3.2	13.0	3.8	7.4		0.5		0.2			28.1
4. **Acquisition of Montrose site lands**	0.3	1.2	1.2	1.2	1.2							5.1
TOTAL PLAN CAPITAL COSTS												
Region of Waterloo*	22.1	3.2	13.0		20.1	5.1			21.3	6.2	8.1	99.1
Guelph	4.7			21.3			0.5		0.2		21.3	48.0
Brantford	6.8			3.8						3.5	3.6	17.7
Others	8.8	1.2	1.2	1.2	1.2							13.6
Total**	42.4	4.4	14.2	26.3	21.3	5.1	0.5		21.5	9.7	33.0	178.4
OPERATING AND MAINTENANCE COSTS												
Sewage Treatment												
Region of Waterloo*	2.5	14.2	14.6	14.9	15.7	17.5	17.9	18.2	19.8	20.3	20.9	176.5
Guelph	.9	5.8	6.0	6.8	7.2	7.4	7.9	9.2	9.7	10.3	11.7	82.9
Brantford	.8	4.2	4.2	4.3	4.4	4.5	4.6	4.7	4.8	5.1	5.4	47.0
Sub-Total	4.2	24.2	24.8	26.0	27.3	29.4	30.4	32.1	34.3	35.7	38.0	306.4
Water Supply												
Region of Waterloo*			0.1	0.2	0.3	0.4	0.6	0.7				2.3
Guelph								<0.01	0.9	1.1	1.4	3.4
Brantford					0.1	0.21	0.4	0.5	0.6	0.9	1.1	3.8
Sub-Total			0.1	0.2	0.4	0.6	1.0	1.2	1.5	2.0	2.5	9.5
Total O&M Costs	4.2	24.2	24.9	26.2	27.7	30.0	31.4	33.3	35.8	37.7	40.5	315.9

* Region of Waterloo refers to major capital works in Waterloo, Kitchener and Cambridge.

** Total plan capital costs include the costs of sewage treatment plant expansions.

*** Operating and maintenance costs are cumulative for the preceding five years.

Acquisition of the remaining land as it becomes available is one method of preserving the reservoir lands and maintaining the option of building the dam and reservoir in the future. In estimating the costs of plan A4 it was asumed that acquisition of all the lands required will take place by the year 2001. Subsequently, the land can either be sold, used for construction of a dam and reservoir, or preserved for other uses. These options for possible actions after 2001 are not incorporated into Table 12.1.

Rural non-point source controls are estimated to cost approximately $5.5 million discounted at 6 percent over the fifty year planning period (Ref. Tech. Report No. 27). Economic benefits such as savings in soil, time and fertilizer require more research and were not evaluated in this study. Work is currently being carried out in the United States and Canada to provide information on the benefits and effectiveness of rural non-point source controls.

Cost for projects dealing with localized flood control, water supply and water quality are given in Chapter 7. Since these projects would be required for each plan, they do not affect the evaluation of the final plans and their costs are not included in the total cost of any of the plans.

12.3 Flexibility

As well as meeting, to a satisfactory extent, the water management objectives, plan A4 includes provision for the acquisition of the Montrose reservoir site. Preserving the option of building the Montrose reservoir provides a safety factor which would allow for additional river flow augmentation for water quality improvement, water supply, and additional storage for flood control. It allows for the uncertainties inherent in mathematical modelling and predictions with respect to flood flows and water quality, and in projections of population, economic development and land use changes. Further, it maintains flexibility in relation to possible changes in recreational values or needs.

The preservation of the Montrose reservoir lands for possible future water management needs could be accomplished by any one of the following land use measures:

a) local municipal zoning regulations preserving the land for agricultural use
b) Ministry of Municipal Affairs and Housing zoning order preserving the land for agricultural uses only
c) purchase of land from willing sellers
d) expropriation of lands
e) combination of the above methods.

If zoning methods are implemented, the agricultural land use will be preserved. However, the property owners may find that the value of their land would increase less rapidly because of restricted development prospects. Methods c) and d) provide maximum possible protection of the site. The purchase of land from willing sellers has a minimum social impact while expropriation creates more severe social impacts. However, both these options will probably tend to raise land prices. Social and economic impacts could be reduced by lease-back arrangements so that existing land use practices will not be disrupted.

13. IMPLEMENTATION OF WATER MANAGEMENT PLANS BY EXISTING INSTITUTIONS

At present, there is no one agency responsible for implementing all aspects of water management in the Grand river basin. For example, the agency primarily responsible for ensuring protection of water quality and proper development of water supplies is the Ontario Ministry of the Environment (MOE); whereas regional or local municipalities, corporations and individuals have responsibilities for constructing and operating facilities to prevent pollution and supply water. The Ontario Ministry of Natural Resources (MNR) develops policies and guidelines for flood damage reduction. Implementation of floodplain policies in the Grand river basin is carried out by the Grand River Conservation Authority and local municipalities. Control over floodplain development is also administered by the Ministry of Municipal Affairs and Housing (MAH) which provides guidelines to municipalities for developing appropriate policies for floodplain development in their official plans and implementing and zoning by-laws and subdivision approvals. In addition, the mandates of several other agencies from the federal to municipal level include activities covering various aspects of water management (Ref. Tech. Report No. 20).

Several additional provincial statutes and programs are applicable to specific aspects of water management. Examples include the Environment Assessment Act (MOE), the Public Lands Act (MNR) and the Ontario Fisheries Regulations (MNR). The Agricultural Code of Practice developed mutually by the Ontario Ministries of Agriculture and Food, Environment and Housing sets down guidelines to reduce air, soil and water pollution from agricultural sources and provide separation distances to reduce odour problems.

The federal government also has some involvement relative to water management in the Grand river basin. For example, under the Canada Water Act administered by Environment Canada, a National Flood Damage Reduction Program was set up to encourage mapping of flood risk areas and discourage floodplain development. In Ontario, this program is administered by the Ministry of Natural Resources.

Existing institutional arrangements provide an initial basis for governments and the Grand River Conservation Authority to carry out the preferred water management plan. However, the complexities of implementation are acknowledged and must be recognized for the successful implementation of the plan.

The authority to implement various aspects of the preferred plan is divided among several agencies as outlined in Table 13.1. Each agency involved in implementing the plan has differing priorities with respect to carrying out its mandate as well as varying water management priorities. This is a direct result of the range of responsibilities allocated to it through legislation and the overall funding available to carry out these responsibilities. Consequently, in implementing the preferred plan, several problems may arise. For example, agencies may be reluctant to allocate funds for water management projects in view of their other priorities. This, in turn, may affect the timing of development for certain components of the plan. Differing priorities may also cause one agency to consider all or part of the preferred plan for implementation, while another agency may want to consider an alternative plan for implementation. The potential for conflicts between agencies is apparent.

Other impediments to plan implementation may arise, particularly for those plan components which would be carried out by the private sector. For example, the responsibility for undertaking remedial measures for non-point source control would lie primarily with the individual land owner. Monetary or other governmental incentives may be necessary to encourage the application of such measures.

In view of the problems which may arise with respect to plan implementation, it is evident that co-operation and co-ordination among pertinent agencies are essential for the successful implementation of the preferred plan. In order to achieve a comprehensive and co-ordinated approach, it is suggested that a co-ordinating body such as the Grand River Implementation Committee be established to assist governments and agencies in the timely and efficient implementation of the various measures of the plan to meet the water management needs of the basin.

Plan A4 will provide the strategy for guiding the implementation of basin water management by elected representatives, officials and citizens. Most structural projects making up the plan will be reviewed under the Environmental Assessment Act. Non-structural components such as water conservation, rural land use practices to control non-point pollution and protection of the Montrose lands are not subject to the Environmental Assessment Act.

In order to ensure that the selected plan offers the best water management strategy, the plan should be periodically reviewed and re-evaluated as future population and land use trends develop and new technology becomes available. Promising new measures should be investigated and incorporated in the plan. It is recom-

Table 13.1 Principal Agencies Responsible for the Implementation of Water Management Alternatives

Plan Component	Pertinent Statute/ Program	Administering Agency	Implementing Agency	Financial Arrangements
FLOOD DAMAGE REDUCTION				
Floodplain Regulation	Conservation Authorities Act Planning Act Canada Water Act - Flood Damage Reduction Program	MNR MAH Environment Canada and MNR	GRCA Municipalities GRCA	Grant for administering 55% MAH planning study grants Floodplain mapping 90%
Dams and Reservoirs	Conservation Authorities Act Lakes and Rivers Improvement Act Municipal Act	MNR MNR MAH	GRCA	Provincial grant 55%
Dyking and Channelization	Conservation Authorities Act Municipal Act	MNR MAH	GRCA Municipalities	Provincial grant 55%
Floodplain Acquisition	Conservation Authorities Act Municipal Act	MNR MAH	GRCA Municipalities	Provincial grant 55%
Flood Proofing	Conservation Authorities Act	MNR	GRCA	100% of cost assumed by property owner
Flood Forecasting and Warning	Conservation Authorities Act	MNR	GRCA	Provincial grant 55%
Rural Land Use Practices	The Drainage Act The Tile Drainage Act The Planning Act	OMAF OMAF MAH	OMAF OMAF Municipalities	Provincial grant 33-1/3% Secured loans not to exceed 75% of total cost of drainage works MAH planning study grants
WATER QUALITY				
Design, Construction and Maintenance of STPs	Ontario Water Resources Act Municipal Act Public Utilities Act Regional Municipality of Waterloo Act	MOE MAH MAH MAH	MOE Municipalities Municipalities Regional Municipality of Waterloo	Provincial grant available to municipalities up to 15% of net capital cost
Monitoring and Controlling Contaminants	Ontario Water Resources Act Environmental Protection Act Pesticides Act Fisheries Act (Canada) Municipal Act Regional Municipality of Waterloo Act	MOE MOE MOE MNR MAH MAH	MOE MOE MOE MNR Municipalities Regional Municipality of Waterloo	
Flow Regulation	Conservation Authorities Act	MNR	GRCA	
Rural Land Use Practices	Farm Productivity Incentive Program The Planning Act	OMAF MAH	OMAF	Provincial grant 40% up to $3,000 per farmer
WATER SUPPLY				
Design, Construction and Maintenance of Water Works	Ontario Water Resources Act Public Utilities Act Regional Municipality of Waterloo Act Local Improvement Act	MOE MAH MAH MAH	MOE Municipalities Regional Municipality of Waterloo Municipalities	Provincial grant available to municipalities up to 15% of net capital costs
Water Abstraction	Ontario Water Resources Act Pits and Quarries Act	MOE MNR	MOE MNR	
Flow Regulation	Conservation Authorities Act	MNR	GRCA	

* Small communities may receive up to 75% of net capital cost

mended that the selected basin plan should be reviewed on an on-going basis and re-evaluated every five years.

13.1 Who Pays For The Plan

Costs of water management capital projects are generally shared between the municipalities and the provincial and federal governments. These cost-sharing arrangements vary depending upon the given situation. In the past, the following cost-sharing arrangements among provincial and municipal governments have been used for the various components related to achieving the water management objectives addressed by the basin study (Table 13.2).

Table 13.2 Cost Sharing Arrangements for Implementing Water Management Plans

Components of Water Management Plans	Implementing Agency	Cost-Sharing Arrangements
1. Dyking and Channelization	GRCA	45% Authority* (member municipalities); 55% Province
2. Reservoir and Lands	GRCA	45% Authority* (member municipalities); 55% Province
3. Sewage Treatment Plants	Individual Municipality	85% Individual Municipality; 15% Province
4. Water Supply Projects	Individual Municipality	85% Individual Municipality; 15% Province

* The Grand River Conservation Authority is eligible for a supplementary grant based on the availability of provincial funds

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Technical Reports

Technical reports have been published in limited numbers and are available from the Grand River Conservation Authority, Community Relations Division, Box 729, Cambridge, Ontario. Out of print copies are available from the libraries listed in "List of Libraries Where Technical Reports Are Distributed" following "Technical Reports."

Title	Published Reports	Draft Report	Out of Print
1. Field Determination of the Critical Nutrient Concentrations for Cladophora in Streams and Their Importance in Waste Load Management – 1976	X		X
2. Application of Underwater Light Measurements in Nutrient and Production Studies in Shallow Rivers – 1976	X		X
3. Upper Grand River Basin Reservoir Yield Study – 1976	X		X and superceded by Tech. Report No. 38
4. Central Grand River Basin Waste Assimilation Study – 1976	X		X
5. Streamflow Analysis at the Woolner Flats Induced Infiltration Site – 1976	X		X and superceded by Tech. Report Nos. 35 and 38
6. Evaluation of Three Selected Watershed Models – 1979	X		X
7. Nutrient-Growth Relationships for Potamogeton Pectinatus and the Re-evaluation of Established Optimal Nutrient Levels for Cladophora Glomerata in Southern Ontario	X		X
8. Existing and Future Land Use Activities Within the Grand River Basin – 1981	X		
9. Lower Grand River Basin – Waste Assimilation Study – 1977	X		X
10. Ground Water Resources in the Grand River – 1981	X ($10 a copy)		
11. Continuous Monitoring of Dissolved Oxygen – 1981	X		
11a Continuous Monitoring of Dissolved Oxygen – 1981	X		

Technical Reports (cont.)

Title	Published Reports	Draft Report	Out of Print
12. Population Projections for Municipalities Within the Grand River Basin — 1981	X		X
13. Water Quality Requirements for Sport Fish in the Grand River Watershed	X		
14. Aquatic Plant Model Derivation and Application		X	
15. Plant Community Assessment Techniques — 1981	X		
16. Canagagigue Creek — 1981		X	
17. Upper Grand Basin Studies (Fergus, Elora)		X	
18. Nith River Basin Study		X	
19. Conestogo River Basin Study		X	
20. A Review of Mandates and Responsibilities for Water Management in the Grand River Basin — 1980		X	
21. Social Impact Assessment Perception & Reality — 1981	X		
22. The Use of Screening Models for Planning of Grand River Basin Water Resources — 1982	X		
23. Discounting Procedures in Benefit-Cost Analysis — 1982	X		
24. Economic Evaluation of Recreation Benefits — 1982		X	
25. Analysis of Questionnaire Data Used in Evaluating the Grand River Basin Water Management Plans — 1982	X		
26. Existing and Future Water Demands For the Grand River Basin		X	
27. Rural Non-point Source Pollution and Control — 1982	X		
28. Urban Non-point Source Pollution and Control — 1982	X		
28a Storm Model Evaluation		X	
29. Mixing Zone Studies		X	

Technical Reports (cont.)

Title	Published Reports	Draft Report	Out of Print
30. Water Quality Simulation Models and Modelling Strategy for the Grand River Basin		X	
31. Spills Dispersion		X	
32. Project Investigation Report		X	
33. Reservoir Water Quality		X	
34. Daily Streamflow Data Base		X	
35. Flow Frequency Analysis — 1982		X	
36. Design Floods		X	
37. Application of the HEC-5 Model to the Grand River Basin High and Low Flows		X	
38. Reservoir Operation		X	
39. Flood Damage — 1982		X	
40. Lake Erie to Kitchener Pipeline		X	
41. Sewage Treatment Options in the Grand River Basin		X	
42. Aquatic Plant Survey Findings — 1981	X		
43. Public Consultation Working Groups Report — 1982	X		

List of Libraries Where Technical Reports Are Distributed

Government Libraries

Archives of Ontario
77 Grenville Street,
Toronto, Ontario

Grand River Conservation Authority Library,
400 Clyde Road,
Box 729,
Cambridge, Ontario

Ministry of Environment,
Main Library,
1st Floor,
135 St. Clair Avenue West,
Toronto, Ontario

Ministry of Natural Resources
Library
Queen's Park, Whitney Block,
Toronto, Ontario

Office of the Director of the
Legislative Library,
Research and Information Services,
180 Bloor Street West,
Toronto, Ontario

Upper Thames River Conservation Authority Library,
Box 6278, Station D,
London, Ontario

Public Libraries

Arthur Public Library,
Arthur, Ontario

Brantford Public Library,
106 Main Street West,
Dunnville, Ontario

Caledonia Public Library,
Caithness Street West,
Caledonia, Ontario

Cambridge Public Library,
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Fergus Public Library,
190 St. Andrew Street West,
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85 Queen Street North,
Kitchener, Ontario

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12 William Street,
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Waterloo Public Library,
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Wellington County Public Library,
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Conestogo College, Doon Campus,
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Kitchener, Ontario

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McMaster University,
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Glossary

ADVANCED SEWAGE TREATMENT — Any new treatment process beyond conventional activated sludge sewage treatment. Advanced treatment is designed to remove pollutants which are not adequately removed by conventional processes. The advanced in-plant treatment processes considered at Waterloo and Kitchener were:

- nitrification to convert toxic ammonia to nitrates (which are relatively harmless at concentrations less than 10 mg/L)
- dual media filtration to remove organics, suspended solids and phosphorus
- carbon adsorption to remove organics, suspended solids and toxic substances

Two advanced treatment processes were considered at Guelph to provide additional phosphorus removal. The first process considered chemical treatment of the RBC effluent and modification of the existing filters. The second, more expensive process considered chemical treatment of the RBC effluent, followed by filtration in a new deep-bed multi-media filter installed before the existing filter.

AQUIFER — A saturated permeable geologic unit that can transmit significant quantities of water under ordinary hydraulic gradients.

ARTIFICIAL RECHARGE — A process of augmenting the natural infiltration of precipitation or surface water into underground formations by some method of construction, spreading of water, or by artificially changing natural conditions. Recharge methods include water spreading, recharging through pits, excavations, wells and shafts. In this study, water for artificial recharge is furnished by surface water from a nearby watercourse.

BIOCHEMICAL OXYGEN DEMAND (BOD) — The amount of oxygen required to decompose (oxidize) a given amount of organic compounds to simple, stable substances. The BOD value usually reported is the amount of oxygen consumed in milligrams per litre of water over a period of 5 days at 20°C under laboratory conditions.

BIOTA — Species of all the plants and animals occurring within a certain area or region.

BIOMASS — The weight of living material, usually expressed as dry weight per unit area.

CONVENTIONAL ACTIVATED SLUDGE SEWAGE TREATMENT (CONVENTIONAL OR SECONDARY TREATMENT) — A combination of physical and biological processes to remove organic matter from solution. Raw wastes are first passed through protective coarse screens to remove large material. This is followed by grit settling where inorganic matter is precipitated out before the wastes are passed through a comminuter that shreds the remaining solids. Primary settling is next where organic solids are collected and piped as raw sludge to the primary digestion tank. Liquid wastes drawn from the top of the primary settling tank are passed to the aeration tank where microorganisms oxidize the organic fraction of the waste. This oxidized waste is then held for a brief period in a final settling tank. The sludge settling at this point is termed activated sludge and is pumped back to the inlet of the aeration tank. Clarified liquid decanting from the settling tank is chlorinated before discharged to the nearest stream or river. Sludge collected in the digesters is held in a closed environment where anaerobic bacteria further oxidize it and is disposed of when fully digested. All plants in the Grand river basin employ chemical addition, in the form of metallic salts, for phosphorus removal (CAS-P).

COST-EFFECTIVENESS — The achievement of the maximum possible benefit for a given investment.

DETRITUS — Unconsolidated sediments comprised of both inorganic and dead and decaying organic material.

DISCHARGE AREA — That portion of the drainage basin in which the net saturated flow of ground water is directed towards the water table. The water table is usually at or very near the surface. Ground water flows from recharge areas to discharge areas.

DISCHARGE LAGOON (WASTE STABILIZATION PONDS) — A treatment facility which provides secondary treatment, usually for small municipalities and industries. Wastewater is directed to a pond where biological processes remove organic matter from the solution. Effluent is dicharged to a receiving watercourse either seasonally (ie. spring and fall) or annually (once a year). The sludge which settles to the bottom of the pond is collected and disposed of.

DIURNAL — Occurring once a day, ie. with a variation period of one day; occurring in the daytime or during a day.

DUAL-MEDIA FILTRATION (SAND FILTRATION) — See FILTRATION

Glossary (cont.)

EFFLUENT — The fluids discharged from domestic, industrial and municipal waste collection systems or treatment facilities.

ENVIRONMENTALLY SENSITIVE AREA — Those landscapes of inherent biological sensitivity. The areas may contain: aquifer recharge functions; headwaters, significant wildlife breeding or overwintering habitats; vital ecological functions; rare or endangered species or other combinations of habitat and landform which could be valuable for scientific research or conservation education.

EXTENDED AERATION SEWAGE TREATMENT PLANT — A treatment facility which provides secondary treatment and is generally used by small municipalities. This process is identical to the activated sludge process in its biological application, but has no primary settling and the solids contained in the wastewater are oxidized through an extended aeration period. The activated sludge that settles in the basin is either pumped from the bottom and hauled away or is passed through aerobic digesters and is disposed of either by spreading on farmland, lagooning, or drying on sand beds. The effluent is discharged to a receiving watercourse.

FILTRATION — A physical-chemical process for separating suspended and colloidal impurities from water by passage through a bed of granular material. It is used as an advanced wastewater treatment process to increase removal of suspended solids, turbidity, phosphorus, BOD, heavy metals, bacteria and other substances. Two types of filters referred to in this study are dual-media filters and multi-media filters. Dual-media filters consist of a layer of anthracite coal and a layer of fine sand. Multi-media filters often consist of layers of coal, sand and garnet.

HYDRAULIC EXPANSION — An increase in the hydraulic capacity of a conventional sewage treatment plant to accommodate increases in sewage flow.

INDUCED INFILTRATION — A process by which river water is induced to flow from the river into an adjacent aquifer through the pumping of wells in the aquifer.

INFILLING — Refers to development in the flood fringe which occurs in the midst of existing development in an urban and/or municipally recognized community. This development may occur on small lots which are surrounded by existing development on at least two sides, as opposed to being lots which are set apart or are extremities to existing development.

INSTANTANEOUS STREAMFLOW — The observed streamflow at any given point in time.

MACROPHYTE — The larger aquatic plants, as distinct from the microscopic plants, including aquatic mosses, liverworts and larger algae as well as vascular plants.

MULTI-MEDIA FILTRATION — See FILTRATION

NUTRIENTS — Organic and inorganic chemicals necessary for the growth and reproduction of organisms.

RECHARGE AREA — That portion of the drainage basin in which the net saturated flow of ground water is directed away from the water table. The water table usually lies at some depth. Ground water flows from recharge areas to discharge areas.

REGIONAL STORM — As defined in section 4(g) of Ontario Regulation 356/74. The Regional storm concept originated to provide protection from the devastating flood damages and loss of life that were experienced in 1954 in Etobicoke with the occurrence of the tropical storm known as Hurricane Hazel. Similar damages and human suffering could be experienced in the Grand river basin if similar rainfall conditions occurred there. Presently, the rainfall which fell over Etobicoke during Hurricane Hazel has been designated as the Regional Storm for central and south-western Ontario. It has been so designated on the basis of its occurrence as the largest flood-producing event affecting this part of the Province that has been recorded in recent times. The severity of flooding resulting from a Regional Storm has in the past been predicted by two widely used methods:

- the statistical analysis of existing streamflow records
- the unit hydrograph method such as developed by the United States Soil Conservation Services.

Recent, more exacting floodline studies employ hydrologic computer modelling for simulating the interaction of hydraulic watershed parameters and much more reliable predictions of flood flows are now available. The flows generated by any of the above methods are adjusted to reflect the available Mid-October storage capacity of the upstream flood control reservoirs for land use control purposes.

For the purposes of applying standards for the design of flood control works, the above methods are used with no consideration of the effects of the existing reservoir system.

REGIONAL STORM FLOODLINE — A set of lines on either side of a river or stream showing the highest level which may be reached if a Regional Storm should occur, assuming no reservoirs.

REGULATORY FLOODLINE — A set of lines on either side of a river or stream showing the highest level which may be reached if a Regional Storm should occur, assuming Mid-October conditions within the existing reservoir system.

Mid-October conditions reflect:

- i) the flood storage available in the existing flood control reservoir system in Mid-October according to the policy of the Grand River Conservation Authority.
- ii) the use of the Regional Storm as the design criterion for the establishment of flood flows.

The Regional Storm is a tropical storm or a hurricane and the mid-October meteorological conditions in this portion of the Province of Ontario establish a higher probability for occurrence of a hurricane in the early fall of the year at Mid-October than at any other time of year.

NOTE: In an area where the channel section is upstream of flood control reservoirs the Regulatory Floodline will be equal to the Regional Storm Floodline.

RELIABILITY INDEX (R) — The index number indicating the reliability that actual flows will not be lower than a given target flow or objective. It can be characterized in two different ways:

a) occurrence-based reliability where:

$$R_O = \frac{n-m}{n} \times 100\%$$

where m = the number of failure years
n = the total number of years considered

b) time-based reliability where:

$$RT = \left(1 - \frac{1}{T} \sum_{T} \Delta T \right) \times 100\%$$

where T = the length of the whole period of reservoir operation
ΔT = the duration of a single failure period

RETURN PERIOD — The average number of years within which a given streamflow will be equalled or exceeded. For example, a flood magnitude which has a probability of being equalled or exceeded once in fifty years is referred to as a 50-year flood. Over a long period of record of say, five hundred years, ten such floods would have occurred. Since the return period is the reciprocal of the annual probability of exceedence in any one year, there is a 2 percent probability that the 50-year flood will be equalled or exceeded. However, the probability of a 50-year flood occurring in the next fifty years is approximately 65 percent.

Similarly, the 100-year flood has a 1 percent probability of being equalled or exceeded in any given year and the probability of a 100-year flood occurring in the next one hundred years is approximately 65 percent.

ROTATING BIOLOGICAL CONTACTORS (RBCs) — An aerobic wastewater treatment process which converts ammonia and organic nitrogen to the more stable, less toxic inorganic form (ie. nitrate). In the RBC process, a population of microorganisms is grown and retained on the surface of a number of closely spaced discs. These discs, partially submerged in wastewater, are mounted on a common shaft which is rotated, alternatively exposing the microbial population to the wastewater and to the atmosphere. The fixed film of biomass on the discs, in the presence of oxygen (from air), continually oxidizes ammonia and organic nitrogen. New cellular matter is synthesized from the energy liberated by the oxidation reaction. When the attached mass of microorganisms on the discs reaches an excessive thickness, it is sloughed off the surface of the discs by the shearing force created by the rotation of the discs through the wastewater.

SOURCE AREA — Areas which exhibit a high water table and which contribute to the base flow of rivers and streams.

50-YEAR FLOOD — See RETURN PERIOD

100-YEAR FLOOD — See RETURN PERIOD

Conversion Factors

The following list of equivalents of measures gives the relationships between the International System of Units (SI metric) and English units.

SI (metric) Units to English Units	English Units to SI (metric) Units
Length	
1 km (kilometre) equals 0.62137 mile 1 m (metre) equals 3.2808 feet	1 mile equals 1.609 km (kilometres) 1 foot equals 0.3048 m (metre)
Area	
1 ha (hectare) equals 2.4710 acres 1 km^2 (square kilometre) equals 0.38610 sq. mi (square miles)	1 acre equals 0.40469 ha (hectare) 1 sq. mi (square mile) equals 2.5900 km^2 (square kilometres)
Gradient	
1 m/km (metre per kilometre) equals 5.28 ft/mi (feet per mile)	1 foot per mile equals 0.1893 m/km (metre per kilometre)
Velocity	
1 m/s (metre per second) equals 3.2808 ft/sec (feet per second)	1 foot per second equals 0.3048 m/s (metre per second)
Volume Rate of Flow*	
1 m^3/s (cubic metre per second) equals 35.315 cfs (cubic feet per second)	1 cfs (cubic foot per second) equals 0.028317 m^3/s (cubic metre per second)
1 m^3/d (cubic metre per day) equals 0.0002199 mgd (million gallons per day)	1 mgd (million gallons per day) equals 4546.09 m^3/d (cubic metres per day)
1 L/s (litre per second) equals 13.1981 gpm (gallons per minute)	1 gpm (gallon per minute) equals 0.075768 L/s (litre per second)
1 L/capita•d (litre per capita per day) equals 0.2199 gpcd (gallon per capita per day)	1 gpcd (gallon per capita per day) equals 4.54609 L/capita•d (litres per capita per day)
Volume	
1 m^3 equals 0.0008107 acre foot	1 acre foot equals 1233.482 m^3 (cubic metres)
Mass	
1 (t) tonne equals 1.102 short tons (2,000 pounds)	1 short ton (2,000 pounds) equals 0.90718 (t) tonne

* The term "gallon" refers to the Imperial (Canadian) gallon.

A. GRIC MEMBERS AND STUDY ORGANIZATION

A.1 Members

Present and former members of the Grand River Implementation Committee (GRIC) and their affiliated agencies are listed below. While GRIC was formed in 1972, only persons who were members since September 1977 (the start of the basin study) have been listed.

Grand River Implementation Committee

Chairman
D. N. Jeffs
Director, Water Resources Branch
Ministry of the Environment

Vice-Chairman
G. M. Coutts
General Manager
Grand River Conservation Authority

Present Members

P. Burns, Policy Advisor
Functions Policy Section
Local Government Organization Branch
Ministry of Municipal Affairs and Housing

J. Johnston
Drainage Co-ordinator
Drainage Section
Foodland Development Branch
Ontario Ministry of Agriculture and Food

J. McFadden
Regional Conservation Authorities Program Supervisor
Central Region
Ministry of Natural Resources

L. G. Simmonds, Manager,
Municipal and Private Abatement
West Central Region
Ministry of the Environment

J. Darrell, Planning Co-ordinator
Office of the Assistant Deputy Minister of Community Planning
Ministry of Municipal Affairs and Housing

T. M. Kurtz
Asst. Director Services
Conservation Authorities and Water Management Branch
Ministry of Natural Resources

S. Salbach, Supervisor
Quality Protection Section
Water Resources Branch
Ministry of the Environment

A. F. Smith, Co-ordinator
Grand River Basin Water Management Study

Former Members

N. Harris, represented
Management Board of Cabinet Secretariat

C. Lonero, Economist,
Economic Development Branch,
Ministry of Treasury and Economics

R. Hunter, Supervisor,
Land Management and Program Evaluation,
Conservation Authorities and Water Management Branch,
Ministry of Natural Resources

G. Pearce
West Central Region
Ministry of the Environment
now with Envirosearch Ltd.

T. Spearin, Manager
Program Planning and
Budgeting Group
Ministry of Industry and
Tourism

P. Wormwell, represented
Management Board of Cabinet
Secretariat
now with Land and Waters Group
Ministry of Natural Resources

F. Shaw, Deputy Regional
Director,
Central Region,
Ministry of Natural Resources

R. Stewart, Manager,
Technical Support,
West Central Region,
Ministry of the Environment

A.2 Study Organization

The work of the basin study was guided by a steering and co-ordinating committee called the Grand River Implementation Committee (GRIC) made up of members from five participating ministries and agencies. Present member agencies of GRIC include:

Ontario Ministry of Agriculture and Food
Ontario Ministry of the Environment
Ontario Ministry of Municipal Affairs and Housing
Ontario Ministry of Natural Resources
Grand River Conservation Authority

The functions of GRIC involve:

a) planning and directing the Grand River Basin Water Management study
b) co-ordinating the implementation of the recommendations of the 1971 report, Review of Planning for the Grand River Watershed
c) providing a forum for the exchange of information among provincial and municipal representatives and area residents.

The technical work of the basin study was carried out by five sub-committees:

a) Hydrologic Sub-Committee
b) Water Quality Sub-Committee
c) Facilities and Operations Sub-Committee
d) Public Consultation Sub-Committee
e) Water and Related Land Use Sub-Committee

Members of these sub-committees were from agencies represented on GRIC and from local municipalities.

The technical sub-committees' activities were, in turn, co-ordinated by the Grand River Basin Study Team who reported directly to GRIC. The basin study team was made up of the technical sub-committee chairmen plus one additional representative from the Ministry of the Environment and the Ministry of Natural Resources, a representative from the Ontario Ministry of Agriculture and Food and a representative from the municipal water managers in the basin.

In addition to the five main sub-committees, several advisory groups were formed to carry out more detailed investigation for the main sub-committee. The organization is illustrated in Figure A.1 and the members are listed in Appendix G.

Two important advisory groups were the Public Involvement Program Advisory Group (PIPAG) and the four Public Consultation Working Groups, both of whom provided advice to GRIC and the study team through the Public Consultation Sub-Committee. Basin residents with diverse backgrounds and interests served on these groups.

The municipalities were kept informed of the study's progress through the efforts of the municipal involvement group. This group, composed of GRIC members, arranged several information meetings with the basin's municipal representatives.

As a multi-agency committee, GRIC is responsible through the Ministry of the Environment directly to the Cabinet Committee on Resources Development. Throughout the study, GRIC has kept the committee informed by submitting progress reports and results of basin study investigations.

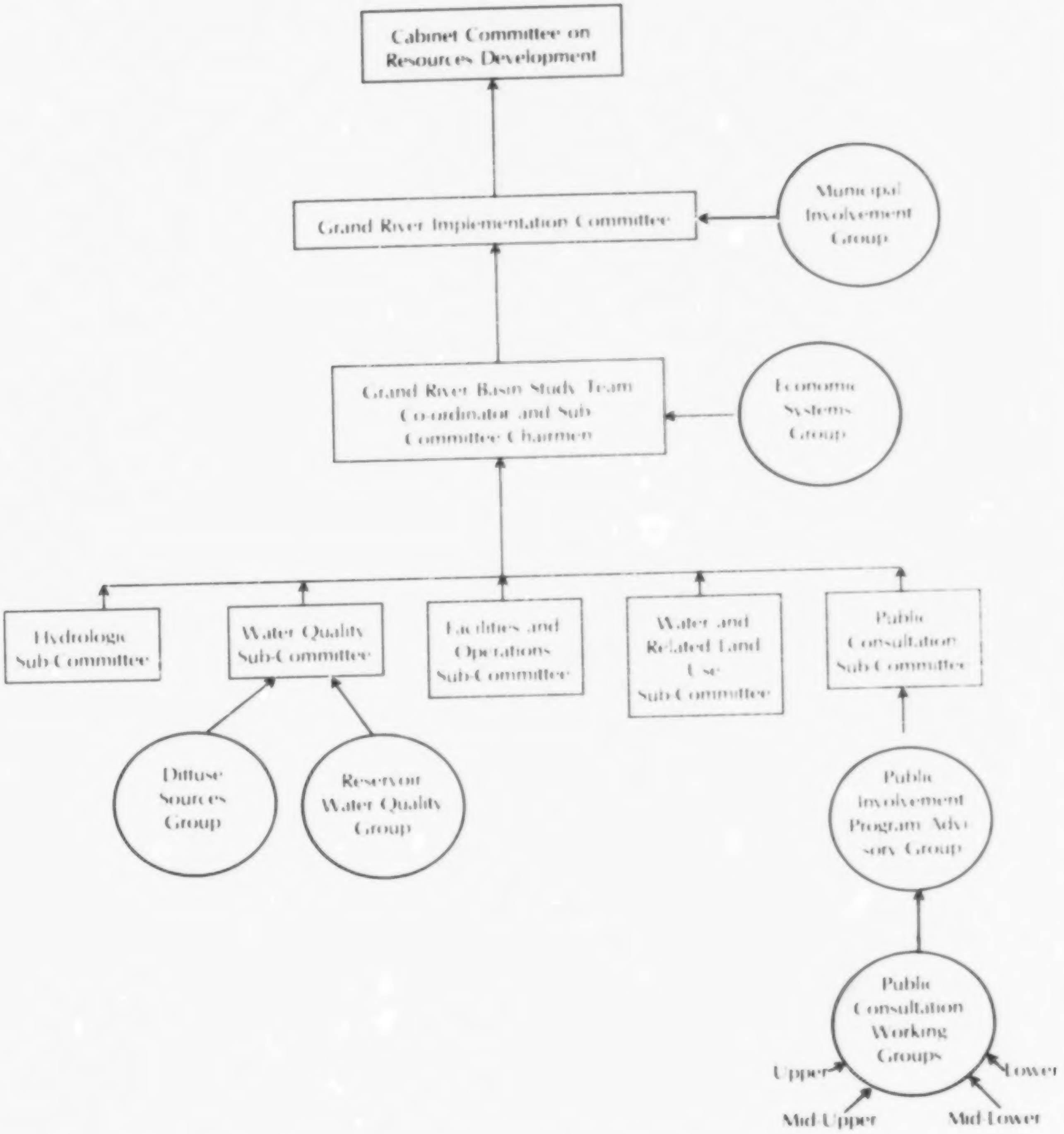
Cabinet Committee on Resources Development
Grand River Implementation Committee
Municipal Involvement Group
Grand River Basin Study Team Co-ordinator and Sub-Committee Chairmen
Economic Systems Group
Hydrologic Sub-Committee
Water Quality Sub-Committee
Facilities and Operations Sub-Committee
Water and Related Land Use Sub-Committee
Public Consultation Sub-Committee
Diffuse Sources Group
Reservoir Water Quality Group
Public Involvement Program Advisory Group
Public Consultation Working Groups
Upper
Lower
Mid-Upper
Mid-Lower

Figure A.1 Organization of the Grand River Basin Water Management Study

Number/
Numéro

2

GRAND RIVER BASIN
WATER MANAGEMENT STUDY

APPENDICES

GRAND RIVER IMPLEMENTATION COMMITTEE

1982

GRAND RIVER BASIN
WATER MANAGEMENT STUDY

APPENDICES

Ontario

GRAND RIVER IMPLEMENTATION COMMITTEE

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GRAND RIVER BASIN WATER MANAGEMENT STUDY

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Ontario

GRAND RIVER IMPLEMENTATION COMMITTEE

1982

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- **A.2** Study Organization A.2

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- **C.2** An Economic Measure of Water Supply Benefits C.3
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REFERENCES R.1

GRAND RIVER BASIN WATER MANAGEMENT STUDY

APPENDICES

ERRATA

Please note the following corrections as underlined:

Page B.7 to B.10 - Table B.2 Summary of Preliminary Water Management Plans for a Medium Population Projection

The title "Flood Prevention" should read Flood Damage Reduction

Page 10.B - Table B.2

Plan	Flood Damage Reduction
2E	remove 8)

Page B.12 - Table B.2

Plan	Water Quality
9B	Sewage Treatment: Kitchener - Nitrification, Filtration, 1981 Waterloo - Nitrification, Filtration, 1981 Guelph - Chemical Treatment and Multi-Media Filtration, 1981

Page B.23 - Table B.7 Summary Table of Costs and Benefits for Main Plans

Plan	Water Quality
A Option 1	Sewage Treatment: Kitchener - Nitrification, Filtration, 1981 Waterloo - Nitrification, Filtration, 2001

/...2

GRAND RIVER BASIN WATER MANAGEMENT STUDY

APPENDICES

ERRATA (Cont'd.)

A Option 4	Flood Damage Reduction
	Same as Plan A, Option 1 Acquire Montrose Reservoir land for possible future use
	91%

Page B.24 - Table B.27

Plan	Water Quality
B Option 1	Sewage Treatment:
	Kitchener - Nitrification, Filtration, 2001

Page B.32 - Table B.14 Evaluation Grading System for Water Quality

Grading	Dissolved Oxygen Water Quality Index - Speed River
Fair	9-20

Page $.6 - Table E.2 Municipal Sewage Treatment Plants in the Grand River Basin

Sewage Flows - 1979

Plant Capacity	1979
x 10^3 m^3/d or lagoon size in hectares	Average Daily Flow x 10^3 m^3/d

Page G.2 - Hydrologic Sub-Committee (continud)

Participating Staff	D. Walmsley

Page G.5 - Diffuse Sources Group

June 29, 1982

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e) Water and Related Land Use Sub-Committee

Members of these sub-committees were from agencies represented on GRIC and from local municipalities.

The technical sub-committees' activities were, in turn, co-ordinated by the Grand River Basin Study Team who reported directly to GRIC. The basin study team was made up of the technical sub-committee chairmen plus one additional representative from the Ministry of the Environment and the Ministry of Natural Resources, a representative from the Ontario Ministry of Agriculture and Food and a representative from the municipal water managers in the basin.

In addition to the five main sub-committees, several advisory groups were formed to carry out more detailed investigation for the main sub-committee. The organization is illustrated in Figure A.1 and the members are listed in Appendix G.

Two important advisory groups were the Public Involvement Program Advisory Group (PIPAG) and the four Public Consultation Working Groups, both of whom provided advice to GRIC and the study team through the Public Consultation Sub-Committee. Basin residents with diverse backgrounds and interests served on these groups.

The municipalities were kept informed of the study's progress through the efforts of the municipal involvement group. This group, composed of GRIC members, arranged several information meetings with the basin's municipal representatives.

As a multi-agency committee, GRIC is responsible through the Ministry of the Environment directly to the Cabinet Committee on Resources Development. Throughout the study, GRIC has kept the committee informed by submitting progress reports and results of basin study investigations.

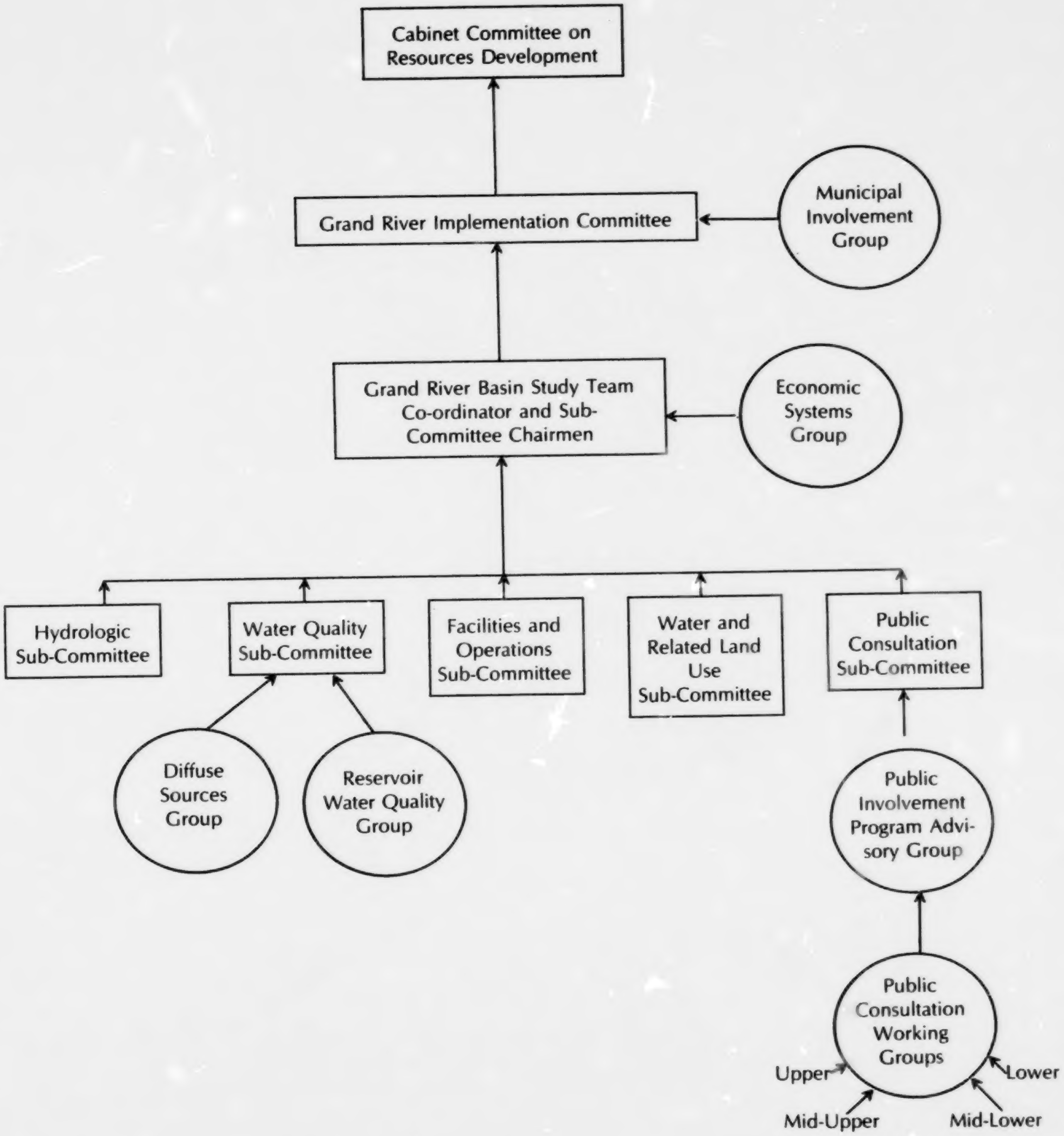

Cabinet Committee on Resources Development
Grand River Implementation Committee
Municipal Involvement Group
Grand River Basin Study Team Co-ordinator and Sub-Committee Chairmen
Economic Systems Group
Hydrologic Sub-Committee
Water Quality Sub-Committee
Facilities and Operations Sub-Committee
Water and Related Land Use Sub-Committee
Public Consultation Sub-Committee
Diffuse Sources Group
Reservoir Water Quality Group
Public Involvement Program Advisory Group
Public Consultation Working Groups
Upper
Lower
Mid-Upper
Mid-Lower

Figure A.1 Organization of the Grand River Basin Water Management Study

B. EVALUATION PROCESS TO SELECT THE MAIN WATER MANAGEMENT PLANS

B.1 Formulation of Water Management Plans

Water management plans were formed by combining various projects such as dams, dykes, sewage treatment plants, and well fields in different ways which would satisfy the basin objectives to varying degrees. Numerous projects identified in Table B.1 were investigated by the basin study and combined to form twenty-six plans.

B.1.1 Plan Generation

Preliminary plans were generated through the use of optimization or screening models. Deviations in plans resulted by varying input parameters such as population and flows or constraints such as maximum day municipal water demands and dissolved oxygen levels.

Two screening models were formulated for the study. One model, a linear programming screening model, incorporated an optimization algorithm to formulate management plans. However, it did not allow for population growth. The second model was an interactive project staging model which incorporated population growth (Ref. Tech. Report No. 22). Rather than using an optimization routine, projects were selected for input into the model. Both models imposed water quality and water consumption constraints and included measures of flood benefits and project costs. The results of the screening models were supplemented by more accurate water quantity and quality simulation results.

Flood Damages

Flood damages were included in the screening models in the form of reductions in average annual flood damages resulting from the specified projects. Only the damage centres which are affected by more than one project solution were considered in the preliminary economic analysis.

The projects considered for reducing flood damages were: dams; channelization and dyking in Cambridge (Galt and Preston), Paris, Brantford, Caledonia, Dunnville and New Hamburg; flood proofing of existing floodplain structures in all flood damage centres; and floodplain land acquisition in Cambridge(Galt), Paris and Brantford.

Water Quality

The screening models incorporated the results of a steady state water quality assimilation model to assess the impact of wastes discharged from major urban centres upon the dissolved oxygen levels of the river system.

Sewage treatment plants having potential major effects on basin watercourses were selected for preliminary analysis. These included plants located in the urban centres of Waterloo, Kitchener, Cambridge (Galt and Hespeler) and Brantford. Other sewage treatment plants were excluded from this analysis because of their relatively minor impact on downstream dissolved oxygen levels. However, some of the excluded plants can cause local water quality problems and are examined in separate water quality studies as described in Chapter 7.

The effects of urban and rural non-point sources were considered independently in detailed water quality simulation models and are discussed in Chapters 9 and 10. Simulation results indicate that urban sources have a negligible effect upon dissolved oxygen levels in the main river system. Rural non-point sources have a negligible effect on the dissolved oxygen levels in the Speed river below Guelph, but have some effect on the middle Grand river system.

Two levels of sewage treatment for each plant were identified: (1) conventional treatment; and (2) conventional treatment + advanced treatment. Effluent quality improves with the level of treatment.

Conventional treatment refers to the standard biological treatment (activated sludge) with chemical treatment for phosphorus removal presently practiced at all of the basin's major sewage treatment plants. This type of treatment removes approximately 90 to 95 percent of the carbonaceous oxygen-demanding wastes and suspended solids and removes phosphorus to about 1 mg/L (80 percent reduction).

Advanced sewage treatment in this report refers to any new treatment process beyond conventional treatment. Advanced treatment is designed to remove pollutants which are not adequately removed by conventional processes. The advanced in-plant treatment processes considered at Waterloo and Kitchener were:

- nitrification to convert toxic ammonia to nitrates (which are relatively harmless at concentrations less than 10 mg/L)
- dual-media filtration to remove organics, suspended solids and phosphorus
- carbon adsorption to remove organics, suspended solids and toxic substances.

Two advanced treatment processes were considered at Guelph to provide additional phosphorus removal. The first process considered chemical treatment of the RBC effluent and modification of the existing filters. The second, more expensive process considered chemical treatment of the RBC effluent, followed by filtration in a new deep-bed multi-media filter installed before the existing filter.

Table B.1 Water Projects Investigated in the Grand River Basin Water Management Study

Structural Projects

Project	Reduce Flood Damages	Provide Adequate Water Supply	Improve Water Quality	Reference	Comment
1. Reservoirs					
Montrose (multi-purpose)	X	X	X	Plan B, Chapter 9	
Montrose (single-purpose)	X			Plan C2, C3, Chapter 9	
Ayr	X	X	X	Plan 5, Appendix B Chapter 7	
Nithburg	X		X		
Everton			X	Plan A3, Chapter 9	
St. Jacobs	X			Plan C1, Chapter 9	
Wallenstein	X		X	Appendix B, Plan 3,11	
Salem	X			Appendix B, Plan 3B	
Freeport	X			Appendix B, Plan 11	
Hespeler	X			Tech. Report 32	
2. Dyking & Channel Improvements					
a) Grand Valley	X			Chapter 7	
b) New Hamburg	X			Chapter 7	
c) Hespeler	X			Chapter 7	
d) Preston	X			Chapter 7	
e) Galt	X			Chapter 9, Plan A	
f) Paris	X			Chapter 9, Plan A	
g) Brantford	X			Chapter 9, Plan A	
h) Caledonia	X			Chapter 9, Plan A	
i) Dunnville	X			Chapter 9, Plan A	
3. Flood Proofing	X			Appendix B, Plan 1C	effective for flood fringe areas
4. Point Source Controls					
a) conventional treatment			X	Chapter 9, Plan A1	
b) advanced treatment					
(i) nitrification			X	Chapter 9, Plan A1	recommended for Kitchener-Waterloo STP
(ii) dual-media filtration			X	Chapter 9, Plan A1	recommended for Kitchener-Waterloo STP
(iii) chemical treatment and multi-media filtration			X	Chapter 9, Plan A1	recommended as one option to remove additional phosphorus at Guelph STP
(iv) activated carbon			X	Tech. Report 41	not cost-effective
(v) land treatment			X	Tech. Report 41 File Reports MOE- 1974, 1975	requires extensive amounts of land, may be viable for small communities, still under investigation

Table B.1 Water Projects Investigated in the Grand River Basin Water Management Study (Continued)

Structural Projects

Project	Reduce Flood Damages	Provide Adequate Water Supply	Improve Water Quality	Reference	Comment
5. Non-Point Source Controls					
a) Urban				Chapter 9	
(i) storage	X		X	Tech. Report 28	
(ii) treatment			X		
b) Agriculture				Chapter 9	
(i) waterway stabilization	X		X	Tech. Report 27	
(ii) bank stabilization	X		X		
(iii) fencing for livestock			X		
(iv) buffer strips	X		X		
(v) manure storage			X		
Instream Controls					a) to be studied further
(a) weirs			X		b) insufficient depth
(b) aerators			X		c) high environmental impact to stream
(c) cropping			X	c) File Report 1980	
(d) oxygen injection			X		d) possible on Speed river
6. Short pipeline for sewage treatment — Guelph to Glen Morris			X	File Report 1980	— costs over 10 million dollars — may affect raw water quality for Brantford water supply
7. Great Lakes Pipeline		X		Chapter 9	— most expensive water supply option
8. Recharge of groundwater		X		Chapter 9 Tech. Report 10, 32	Mannheim recharge scheme
9. Induced infiltration		X		Tech. Report 10, 32	
10. New Groundwater Supplies		X		Chapter 9, 11 Tech. Report 10, 32	
11. De-mineralization of groundwater high in sulphates, chlorides		X			expensive, useful for small communities like Plattsville, when demand is less than 2,631 m³/d (0.5 mgd)

Table B.1 Water Projects Investigated in the Grand River Basin Water Management Study (Continued)

Non-Structural Projects

Project	Reduce Flood Damages	Provide Adequate Water Supply	Improve Water Quality	Reference	Comment
1. Floodplain Management					
a) floodplain regulations	X			Chapter 9	
b) floodplain acquisition	X			Chapter 9 Appendix B, Plan 1E	
2. Flood Forecasting & Warning	X			Chapter 8	
3. Wetland Preservation	X	only locally	X	Chapter 9	– 7% of watershed in wetlands – approx. 3.5% recharge – approx. 3.5% discharge – important to preserve on Eramosa for flood reduction – important locally not basin wide for water supply
4. Reforestation	X		X		– only 17% of watershed in forest – effective locally not basin wide
5. Water Conservation		X		Chapter 9, Tech. Report No. 26	– defers need for new water supply projects 5 to 10 years – defers need for sewage treatment expansions by approx. 5 years

The level of treatment required at each plant depends upon several factors including the volume of sewage, the capacity of the river to absorb wastes, river flows, and water quality objectives.

Water Supply

In constructing the screening models, only the water demands of the major urban areas of Guelph, Kitchener, Waterloo, Cambridge and Brantford were considered, since most smaller communities have adequate water supplies to meet future demands to the year 2031.

The projects considered to maintain adequate water supplies include:

(1) maintaining river flow through the existing reservoir operation to provide supply for: (i) Mannheim recharge scheme (Kitchener-Waterloo); (ii) infiltration wells (Kitchener-Waterloo); and (iii) direct river takings (Brantford)

(2) ground water extraction (Cambridge, Guelph, Kitchener-Waterloo)

(3) construction of a Lake Erie pipeline (Brantford, Cambridge, Kitchener-Waterloo)

(4) construction of a reservoir pipeline from Montrose or Ayr reservoir sites (Kitchener-Waterloo)

(5) implementation of a water conservation program in major urban areas where warranted.

B.1.2 Water Management Plans

Twenty-six preliminary water management plans were assembled using the projects simulated in the screening models. These plans are described briefly in the following sections. All references with respect to the staging of various plan components are based on a medium population projection.

Plan 1

There are nine versions to plan 1 (plan 1A to 1i). The same water quality projects are incorporated into all component plans except for one version, 1G. Attempts to meet water quality objectives for dissolved oxygen and ammonia nitrogen involve expansion of conventional sewage treatment plants to meet growing population needs plus advanced treatment at Kitchener immediately and at Waterloo in the year 2001. Future treatment on the Speed river will depend to a large extent upon the effectiveness of the recently installed nitrification and filtration facilities at Guelph. However, for estimating plan costs, it has been assumed that additional treatment will be required immediately and these costs have been incorporated into plan 1A. As well as improving water quality by additional sewage treatment, plan 1G incorporates a reservoir at Everton on the Eramosa river to improve water quality in the Speed river below Guelph by augmenting low, summer streamflows.

With the exception of plan 1F, water supply projects for 1 series plans are the same. Additional water supply for Kitchener-Waterloo will be provided by induced infiltration from the Grand river initiated in 1980, and recharge to the Mannheim aquifer from the Grand river in 1991. In the years 1986 and 2001, Cambridge is supplied by additional ground water extracted from Puslinch Township and North and South Dumfries Townships, respectively. Additional supplies are required from the Mannheim recharge system in 2001. Guelph water requirements will be met through further extraction of local ground water in 2011 and expansion of the Arkell recharge system in 2021. An expansion of the Brantford water treatment plant with additional extraction from the Grand river will be required by 1996. Plan 1F differs from other plans since it reduces demands through water conservation methods, thereby postponing the introduction of new water supply projects.

Methods for reducing flood damage vary among the versions of plan 1. For example, plans 1A, 1F and 1G incorporate dyking and channelization projects, whereas plan 1B utilizes a dry or single-purpose reservoir at Salem on the Irvine river. Plan 1C includes flood proofing of existing floodplain structures; plan 1E suggests floodplain land acquisition, and plan 1D provides no flood damage protection. Plan 1H includes the effect of the Nithburg reservoir.

Plan 1i is similar to plan 1A except that land required for the construction of the Montrose reservoir on the Grand river is acquired at market prices as the land becomes available. This plan allows for flexibility in the future. If future water management uncertainties are resolved and the Montrose reservoir is not required, the land can be sold on the market place.

Plan 2

There are 5 versions to plan 2 (plans 2A to 2E). Methods for flood damage reduction incorporate a reservoir at West Montrose for all plans. In plans 2A, 2B, 2C and 2D the reservoir would be multi-purpose. In plan 2E, the reservoir is used strictly for flood reduction. Additional flood control measures include dyking and channelization in plans 2B and 2C.

With the option of flow augmentation in plans 2A, 2B, 2C and 2D, recommended sewage treatment improvements outlined in the 1 series plans apply. However, advanced treatment is delayed at Kitchener and Waterloo to the years 2001 and 2021, respectively. Since no flow augmentation is available in plan 2E, all sewage treatment improvements suggested for 1 series plans are required.

The water supply options for plans 2A, 2B, 2C and 2E are the same as those outlined for plan 1A. Plan 2D differs from the others since water is supplied directly from the Montrose reservoir by pipeline. This option would be considered if water quality conditions prevented abstraction from the Grand river at Kitchener.

Plan 3

Plan 3 provides flood damage reduction through the implementation of a multi-purpose dam near Wallenstein on the Conestogo river. Improvement of water quality involves the expansion or upgrading of sewage facilities in accordance with plan 1A plus flow augmentation from the Wallenstein reservoir. Water supply options are the same as plan 1A.

Plan 4

Plan 4 is a combination of plans 1B and 3. Flood damage reduction is achieved by the implementation of a dry or single-purpose reservoir at Salem. Water quality projects include improved sewage treatment as outlined for plan 1A and flow augmentation from the Wallenstein reservoir. Water supply options are the same as plan 1A.

Plan 5

Plan 5 differs from plan 1A through the utilization of the Ayr reservoir on the Nith river for a limited amount of flood damage reduction (9 to 10 percent at Paris and Brantford) and for water supply to Kitchener, Waterloo and Cambridge.

Plan 6

Plan 6 requires the same flood damage reduction and water quality projects as plan 1A. However, additional water supply for Kitchener, Waterloo, Cambridge and Brantford is provided by a pipeline from Lake Erie. Other great lakes sources considered in the past were Georgian Bay and Lake Huron. However, pipeline schemes from these sources proved considerably more expensive than the Lake Erie option.

Plan 7

There are two versions to plan 7 (plans 7A and 7B). In both plans existing conventional sewage treatment plants are expanded but no advanced treatment is installed at the Waterloo, Kitchener and Guelph sewage treatment plants. In addition, no new flood protection is provided. While these plans are the cheapest, it would be necessary to curtail population growth because of water quality or water supply constraints.

Plan 7A immediately limits growth at Kitchener, Waterloo and Guelph because of violations in provincial water quality objectives for dissolved oxygen.

Plan 7B neglects deteriorating water quality and allows for population growth. However, water shortages become a problem, limiting growth in Kitchener and Waterloo by 1991, in Cambridge by 2021 and in Brantford and Guelph by 2031. These dates could be prolonged 5 to 10 years if water conservation measures are implemented.

Plan 8

Plan 8 consists of the same water quality and water conservation projects as plan 1A. However, the effects of water conservation on the cost and staging of these projects are considered in two versions of the plan (plans 8A and 8B).

Plan 8A reduces the average and maximum day demand by 7 and 15 percent respectively, and delays the time at which water supply projects are required by 5 to 10 years. Sewage treatment expansions are also delayed by approximately 5 years.

Plan 8B reduces the average and maximum day demand by 20 and 23 percent respectively, and defers the requirement for water supply projects by an additional 5 to 15 years and sewage treatment projects by an additional 2 years. These reductions are applicable to the supply portions of any of the other plans should water conservation measures be implemented.

Reductions in flood damages for both plans are achieved by flood proofing existing floodplain structures.

Plan 9

There are two versions to plan 9 (plans 9A and 9B).

Plan 9A is the same as plan 1A with the exception of the water quality projects. Sewage treatment plants are allowed to expand. However, advanced treatment at the Waterloo, Kitchener and Guelph sewage treatment plants is not installed. Under these circumstances water quality conditions will gradually deteriorate.

Plan 9B utilizes the same water supply projects as plan 1A, but examines the case for achieving the highest water quality possible on the Grand and Speed rivers. With advanced sewage treatment at Kitchener, Waterloo and Guelph, plus flow augmentation from the Montrose and Everton reservoirs, 69 percent of the provincial water quality objective for dissolved oxygen is achieved on the Speed river and about 94 percent is achieved on the Grand river. Reductions in flood damages are provided by the Montrose dam.

Plan 10

Plan 10 is the same as plan 1A except it utilizes a single-purpose reservoir at St. Jacobs to reduce flood damages rather than dyking and channelization.

Plan 11

Plan 11 utilizes single-purpose reservoirs at Salem, St. Jacobs and Freeport and one multi-purpose reservoir at Wallenstein. The projects used for water quality and water quantity are the same as plan 1A. In addition, the Wallenstein reservoir provides flow augmentation which would improve water quality.

B.1.3 Summary of Water Management Plans

The twenty-six water management plans are summarized in Table B.2. For each plan the project components are described relative to the water management objectives, and the project costs and benefits are summarized for various discount rates. Table B.3 describes the objectives and measurements used to calculate the percentage of objective completion.

An explanation of how cost and benefits were derived in Table B.2 is discussed in Chapter 10 and an explanation of the discount rate and how it pertains to the study is given in Appendix C.1. The plans of Table B.2 have been prepared for a medium population projection. In order to determine the consequences of varying basin population growth, the basin study analyzed each plan in terms of the other population projections: the low low projection, the low projection and the high projection. The effects of these projections upon costs and benefits are described in Chapter 10 and Appendix B.2 for the four main plans.

Table B.2 Summary of Preliminary Water Management Plans For A Medium Population Projection
(Costs and Benefits are in Millions of 1979 Dollars)

PLAN	PLAN DESCRIPTION:			PRESENT VALUE OF BENEFITS & COSTS				NOTES
	WATER QUALITY	WATER SUPPLY	FLOOD PREVENTION	ITEM	DISCOUNT RATE			
					0%	6%	10%	
1A	Sewage Treatment: Kitchener - Nitrification, Filtration, 1981 Waterloo - Nitrification, Filtration, 2001 Guelph - Chemical Treatment and Multi-Media Filtration, 1981 28% - Speed 23% - Grand	Ground Water: Guelph, Cambridge Surface Water: Kitchener-Waterloo 1991 Cambridge connect to Kitchener-Waterloo 2021 100%	Dykes & Channel Works: Preston, Galt, Paris, Brantford, Caledonia, Dunnville, New Hamburg 91%	1) STP-CAS+Guelph RBC	379	94	54	
				2) STP-New Facilities	77	30	23	
				3) Water Supply	38	14	9	
				4) Reservoirs	0	0	0	
				5) Other Flood Prot.	25	24	23	
				6) Water Sup. Benefits	1078	107	26	
				7) Flood Prot. Benefits	46	14	9	
				8) Net Benefits = (6+7) - (2+3+4+5)	984	53	-20	
1B	Same as Plan 1A 28% - Speed 23% - Grand	Same as Plan 1A 100%	Salem Single-Purpose Reservoir 20%	1) STP-CAS+Guelph RBC	379	94	54	Reservoir is used for flood control only. Reservoir remains dry during non-flood periods.
				2) STP-New Facilities	77	30	23	
				3) Water Supply	38	14	9	
				4) Reservoirs	24	22	21	
				5) Other Flood Prot.	0	0	0	
				6) Water Sup. Benefits	1078	107	26	
				7) Flood Prot. Benefits	10	3	2	
				8) Net Benefits = (6+7) - (2+3+4+5)	949	44	-25	
1C	Same as Plan 1A 28% - Speed 23% - Grand	Same as Plan 1A 100%	Flood Proofing 20%	1) STP-CAS+Guelph RBC	379	94	54	Flood proofing is carried out only where economically justified (i.e. Benefits ≥ Costs)
				2) STP-New Facilities	77	30	23	
				3) Water Supply	88	14	9	
				4) Reservoirs	0	0	0	
				5) Other Flood Prot.	2	2	2	
				6) Water Sup. Benefits	1078	107	26	
				7) Flood Prot. Benefits	10	3	2	
				8) Net Benefits = (6+7) - (2+3+4+5)	971	64	-6	
1D	Same as Plan 1A 28% - Speed 23% - Grand	Same as Plan 1A 100%	None 0%	1) STP-CAS+Guelph RBC	379	94	54	
				2) STP-New Facilities	77	30	23	
				3) Water Supply	38	14	9	
				4) Reservoirs	0	0	0	
				5) Other Flood Prot.	0	0	0	
				6) Water Sup. Benefits	1078	107	26	
				7) Flood Prot. Benefits	0	0	0	
				8) Net Benefits = (6+7) - (2+3+4+5)	963	63	-6	

Note: Percent figures refer to % of objective achieved; except where noted the objectives are: Water Quality = meet a water quality index of 0.0 on the Grand river and on the Speed river; Water Supply = Max. Day Demand; Flood Damage Reduction = zero average annual damages.

Table B.2 Summary of Preliminary Water Management Plans For A Medium Population Projection (Cont'd)
(Costs and Benefits are in Millions of 1979 Dollars)

PLAN	PLAN DESCRIPTION:			PRESENT VALUE OF BENEFITS & COSTS				NOTES
	WATER QUALITY	WATER SUPPLY	FLOOD PREVENTION	ITEM	DISCOUNT RATE			
					0%	6%	10%	
1E	Same as Plan 1A 28% - Speed 23% - Grand	Same as Plan 1A 100%	Land Acquisition in Paris, Galt and Brantford to Regional Storm Flood Line 93%	1) STP-CAS + Guelph RBC 2) STP-New Facilities 3) Water Supply 4) Reservoirs 5) Other Flood Prot. 6) Water Sup. Benefits 7) Flood Prot. Benefits 8) Net Benefits = (6+7) - (2+3+4+5)	379 77 38 0 515 1078 43 491	94 30 14 0 486 107 13 -410	54 23 9 0 468 26 8 -466	
1F	Same as Plan 1A 28% - Speed 23% - Grand	Ground Water and Surface Water Projects same as Plan 1A Water Conservation: Ave. Day reduced 7% Max. Day reduced 15% 100%	Same as Plan 1A 91%	1) STP-CAS + Guelph RBC 2) STP-New Facilities 3) Water Supply 4) Reservoirs 5) Other Flood Prot. 6) Water Sup. Benefits 7) Flood Prot. Benefits 8) Net Benefits = (6+7) - (2+3+4+5)	339 70 35 0 25 734 46 650	87 28 10 0 24 66 14 18	50 22 5 0 23 13 9 -22	Implementation date for most water supply projects deferred by 5-10 years using moderate conservation measures. STP costs in Item 1) are also reduced by water conservation.
1G	Same as Plan 1A Flow Augmentation on Speed River from Everton Reservoir 69% - Speed 23% - Grand	Same as Plan 1A 100%	Same as Plan 1A 91%	1) STP-CAS + Guelph RBC 2) STP-New Facilities 3) Water Supply 4) Reservoirs 5) Other Flood Prot. 6) Water Sup. Benefits 7) Flood Prot. Benefits 8) Net Benefits = (6+7) - (2+3+4+5)	379 77 38 17 25 1078 46 967	94 30 14 16 24 107 14 37	54 23 9 15 23 26 9 -35	
1H	Same as Plan 1A 28% - Speed 23% - Grand	Same as Plan 1A	Nithburg Reservoir 2%	1) STP-CAS + Guelph RBC 2) STP-New Facilities 3) Water Supply 4) Reservoirs 5) Other Flood Prot. 6) Water Sup. Benefits 7) Flood Prot. Benefits 8) Net Benefits = (6+7) - (2+3+4+5)	379 77 38 26 0 1078 1 938	94 30 14 24 0 107 0.3 39	54 23 9 23 0 26 0.2 29	

Note: Percent figures refer to % of objective achieved; except where noted the objectives are: Water Quality = meet a water quality index of 0.0 on the Grand river and on the Speed river; Water Supply = Max. Day Demand; Flood Damage Reduction = zero average annual damages.

Table B.2 Summary of Preliminary Water Management Plans For A Medium Population Projection (Cont'd)
(Costs and Benefits are in Millions of 1979 Dollars)

PLAN	PLAN DESCRIPTION:			PRESENT VALUE OF BENEFITS & COSTS				NOTES
	WATER QUALITY	WATER SUPPLY	FLOOD PREVENTION	ITEM	DISCOUNT RATE			
					0%	6%	10%	
1i	Same as Plan 1A 28% - Speed 23% - Grand	Same as Plan 1A 100%	Dykes & Channel Works same as Plan 1A Acquire Montrose Reservoir Land for possible future use 91%	1) STP-CAS + Guelph RBC	379	94	54	This version of plan assumes: — land acquisition is completed by 2001; — reservoir is not built; — land is resold in 2031.
				2) STP-New Facilities	77	30	23	
				3) Water Supply	38	14	9	
				4) Reservoir Land	0*	4*	5*	
				5) Other Flood Prot.	25	24	23	
				6) Water Sup. Benefits	1078	107	26	
				7) Flood Prot. Benefits	46	14	9	
				8) Net Benefits = (6 + 7) - (2 + 3 + 4 + 5)	984	49	-25	
2A	Sewage Treatment: Kitchener - Nitrification, Filtration, 2001 Waterloo - Nitrification, Filtration, 2021 Guelph - Chemical Treatment and Multi-Media Filtration, 1981 Flow Augmentation: Montrose Reservoir 40% - Speed 58% - Grand	Sames as Plan 1A 100%	Montrose Reservoir Dykes in New Hamburg 54% / 56%	1) STP-CAS + Guelph RBC	379	94	54	
				2) STP-New Facilities	68	17	10	
				3) Water Supply	38	14	9	
				4) Reservoirs	46	42	41	
				5) Other Flood Prot.	1	1	1	
				6) Water Sup. Benefits	1078	107	26	
				7) Flood Prot. Benefits	27/28**	9	5	
				8) Net Benefits = (6 + 7) - (2 + 3 + 4 + 5)	952/ 953	42	-30	
2B	Same as Plan 2A Flow Augmentation: Montrose Reservoir 28% - Speed 58% - Grand	Same as Plan 1A 100%	Montrose Reservoir Dykes and Channel Works same as Plan 1A 96%	1) STP-CAS + Guelph RBC	379	94	54	
				2) STP-New Facilities	68	17	10	
				3) Water Supply	38	14	9	
				4) Reservoirs	46	42	41	
				5) Other Flood Prot.	25	24	23	
				6) Water Sup. Benefits	1078	107	26	
				7) Flood Prot. Benefits	48	15	9	
				8) Net Benefits = (6 + 7) - (2 + 3 + 4 + 5)	949	25	-48	
2C	Same as Plan 2A Flow Augmentation: Montrose Reservoir 28% - Speed 58% - Grand	Same as Plan 1A 100%	Montrose Reservoir Dykes and Channel Works (lower elevation than Plan 2B) 76%	1) STP-CAS + Guelph RBC	379	94	54	
				2) STP-New Facilities	68	17	10	
				3) Water Supply	38	14	9	
				4) Reservoirs	46	42	41	
				5) Other Flood Prot.	20	19	18	
				6) Water Sup. Benefits	1078	107	26	
				7) Flood Prot. Benefits	38	12	7	
				8) Net Benefits = (6 + 7) - (2 + 3 + 4 + 5)	944	27	-45	

Note: Percent figures refer to % of objective achieved; except where noted the objectives are: Water Quality = meet a water quality index of 0.0 on the Grand river and on the Speed river; Water Supply = Max. Day Demand; Flood Damage Reduction = zero average annual damages.

* It was assumed that the land acquired for the Montrose reservoir would be sold in the year 2001.

** A range of flood damage benefits is given for multi-purpose reservoirs. This range reflects variations in the assumed storage volume available in the spring to retain flood flows. Storage volumes will vary with the time of year and the operating rules used for each reservoir.

Table B.2 Summary of Preliminary Water Management Plans For A Medium Population Projection (Cont'd)

(Costs and Benefits are in Millions of 1979 Dollars)

PLAN	PLAN DESCRIPTION:			PRESENT VALUE OF BENEFITS & COSTS				NOTES
	WATER QUALITY	WATER SUPPLY	FLOOD PREVENTION	ITEM	DISCOUNT RATE			
					0%	6%	10%	
2D	Same as Plan 2A Flow Augmentation: Montrose Reservoir 28% - Speed 58% - Grand	Reservoir Pipeline: Kitchener, Waterloo, Cambridge Ground Water: Guelph Surface Water: Brantford 100%	Montrose Reservoir Dykes in New Hamburg 54% / 56%	1) STP-CAS + Guelph RBC 2) STP-New Facilities 3) Water Supply 4) Reservoirs 5) Other Flood Prot. 6) Water Sup. Benefits 7) Flood Prot. Benefits 8) Net Benefits = (6 + 7) - (2 + 3 + 4 + 5)	367 77 111 46 0 918 27/28* 711/ 712	90 30 69 42 0 80 9 -52	53 23 62 41 0 15 5 -106	Net benefits include savings in cost Item 1). Lower costs result from reduced hydraulic STP load caused by water demand falling in response to a higher water price.
2E	Same as Plan 2A 28% - Speed 58% - Grand	Same as Plan 1A 100%	Montrose Single-Purpose Reservoir 24.7 million cubic metres (20,000 acre feet) Dykes in New Hamburg 8) 54% / 56%	1) STP-CAS + Guelph RBC 2) STP-New Facilities 3) Water Supply 4) Reservoirs 5) Other Flood Prot. 6) Water Sup. Benefits 7) Flood Prot. Benefits 8) Net Benefits = (6 + 7) - (2 + 3 + 4 + 5)	379 77 38 46 1 1078 27/28* 943/ 944	94 30 14 42 1 107 9 29	54 23 9 41 1 26 5 -43	
3	Same as Plan 1A Flow Augmentation: Wallenstein Reservoir 28% - Speed 32% - Grand	Same as Plan 1A 100%	Wallenstein Reservoir Dykes in New Hamburg 20%	1) STP-CAS + Guelph RBC 2) STP-New Facilities 3) Water Supply 4) Reservoirs 5) Other Flood Prot. 6) Water Sup. Benefits 7) Flood Prot. Benefits 8) Net Benefits = (6 + 7) - (2 + 3 + 4 + 5)	379 77 38 36 1 1078 10 936	94 30 14 33 1 107 3 32	54 23 9 31 1 26 2 -36	
4	Same as Plan 1A Flow Augmentation: Wallenstein Reservoir 28% - Speed 32% - Grand	Same as Plan 1A 100%	Wallenstein Reservoir Salem Single-Purpose Reservoir 46%	1) STP-CAS + Guelph RBC 2) STP-New Facilities 3) Water Supply 4) Reservoirs 5) Other Flood Prot. 6) Water Sup. Benefits 7) Flood Prot. Benefits 8) Net Benefits = (6 + 7) - (2 + 3 + 4 + 5)	379 77 38 60 1 1078 23 925	94 30 14 55 1 107 7 14	54 23 9 53 1 26 4 -56	

Note: Percent figures refer to % of objective achieved; except where noted the objectives are: Water Quality = meet a water quality index of 0.0 on the Grand river and on the Speed river; Water Supply = Max. Day Demand; Flood Damage Reduction = zero average annual damages.

*A range of flood damage benefits is given for multi-purpose reservoirs. This range reflects variations in the assumed storage volume available in the spring to retain flood flows. Storage volumes will vary with the time of year and the operating rules used for each reservoir.

Table B.2 Summary of Preliminary Water Management Plans For A Medium Population Projection (Cont'd)

(Costs and Benefits are in Millions of 1979 Dollars)

PLAN	PLAN DESCRIPTION:			PRESENT VALUE OF BENEFITS & COSTS				NOTES
	WATER QUALITY	WATER SUPPLY	FLOOD PREVENTION	ITEM	DISCOUNT RATE			
					0%	6%	10%	
5	Same as Plan 1A 28% - Speed 23% - Grand	Ayr Reservoir Pipeline: Kitchener, Waterloo Cambridge Ground Water: Guelph 100%	Ayr Reservoir on Nith River Dykes in New Hamburg 3%	1) STP-CAS+Guelph RBC 2) STP-New Facilities 3) Water Supply 4) Reservoirs 5) Other Flood Prot. 6) Water Sup. Benefits 7) Flood Prot. Benefits 8) Net Benefits = (6+7) - (2+3+4+5)	379 77 131 40 0 894 1 647	94 30 72 36 0 76 0.4 -62	54 23 63 35 0 14 0.3 -107	
6	Same as Plan 1A 28% - Speed 23% - Grand	Lake Erie Pipeline: Brantford, Cambridge, Kitchener, Waterloo Ground Water: Guelph 100%	Same as Plan 1A 91%	1) STP-CAS+Guelph RBC 2) STP-New Facilities 3) Water Supply 4) Reservoirs 5) Other Flood Prot. 6) Water Sup. Benefits 7) Flood Prot. Benefits 8) Net Benefits = (6+7) - (2+3+4+5)	348 75 553 0 25 825 46 218	89 29 278 0 24 66 14 -251	52 22 230 0 23 9 9 -257	
7A	No new sewage treatment methods 0%	Ground Water: Cambridge Surface Water: Brantford 100% up to: 1981 - Kitchener Waterloo, Guelph 2021 - Cambridge 2031 - Brantford	None 0%	1) STP-CAS+Guelph RBC 2) STP-New Facilities 3) Water Supply 4) Reservoirs 5) Other Flood Prot. 6) Water Sup. Benefits 7) Flood Prot. Benefits 8) Net Benefits = (6+7) - (2+3+4+5)	231 0 15 0 0 127 0 112	67 0 4 0 0 7 0 3	40 0 2 0 0 -2 0 -4	Population growth is stopped if water quality criteria are violated or if water supply capacities from conventional sources are exceeded.
7B	No new sewage treatment methods 0%	Ground Water: Kitchener, Waterloo, Cambridge, Guelph Surface Water: Brantford 100% up to: 1991 - Kitchener, Waterloo 2021 - Cambridge 2031 - Brantford, Guelph	None 0%	1) STP-CAS+Guelph RBC 2) STP-New Facilities 3) Water Supply 4) Reservoirs 5) Other Flood Prot. 6) Water Sup. Benefits 7) Flood Prot. Benefits 8) Net Benefits = (6+7) - (2+3+4+5)	310 0 26 0 0 399 0 373	82 0 8 0 0 33 0 25	47 0 4 0 0 5 0 1	Population growth is stopped if water supply capacities from conventional sources are exceeded. Water quality is not impaired.

Note: Percent figures refer to % of objective achieved; except where noted the objectives are: Water Quality = meet a water quality index of 0.0 on the Grand river and on the Speed river; Water Supply = Max. Day Demand; Flood Damage Reduction = zero average annual damages.

Table B.2 Summary of Preliminary Water Management Plans For A Medium Population Projection (Cont'd)

(Costs and Benefits are in Millions of 1979 Dollars)

PLAN	PLAN DESCRIPTION:			PRESENT VALUE OF BENEFITS & COSTS				NOTES
	WATER QUALITY	WATER SUPPLY	FLOOD PREVENTION	ITEM	DISCOUNT RATE			
					0%	6%	10%	
8A	Same as Plan 1A	Same as Plan 1A except demand is reduced by moderate water conservation as in Plan 1F	Flood Proofing	1) STP-CAS+Guelph RBC	339	87	50	Refer to notes for Plan 1F.
				2) STP-New Facilities	70	28	22	
				3) Water Supply	35	10	5	
				4) Reservoirs	0	0	0	
				5) Other Flood Prot.	2	2	2	
				6) Water Sup. Benefits	734	66	13	
				7) Flood Prot. Benefits	10	3	2	
	28% - Speed 23% - Grand	100%	20%	8) Net Benefits = (6+7) - (2+3+4+5)	637	29	-14	
8B	Same as Plan 1A	Ground Water: Cambridge, Guelph Surface Water: Kitchener, Waterloo Brantford Water Conservation: Ave. Day reduced 20% Max. Day reduced 23%	Flood Proofing	1) STP-CAS+Guelph RBC	298	79	46	Implementation date for water supply projects deferred by 10-30 years using extreme conservation measures. STP costs in Item 1) are also reduced.
				2) STP-New Facilities	63	27	21	
				3) Water Supply	30	7	3	
				4) Reservoirs	0	0	0	
				5) Other Flood Prot.	2	2	2	
				6) Water Sup. Benefits	287	18	1	
				7) Flood Prot. Benefits	10	3	2	
	28% - Speed 23% - Grand	100%	20%	8) Net Benefits = (6+7) - (2+3+4+5)	202	-15	-23	
9A	No new sewage treatment methods	Same as Plan 1A	Same as Plan 1A	1) STP-CAS+Guelph RBC	379	94	54	Water quality deteriorates with growing population.
				2) STP-New Facilities	0	0	0	
				3) Water Supply	38	14	9	
				4) Reservoirs	0	0	0	
				5) Other Flood Prot.	25	24	23	
				6) Water Sup. Benefits	1078	107	26	
				7) Flood Prot. Benefits	46	14	9	
	0% - Speed 0% - Grand	100%	91%	8) Net Benefits = (6+7) - (2+3+4+5)	1061	83	3	
9B	Sewage Treatment: Kitchener - ACA, 1981 Waterloo - Filter, 1981 Guelph - Chemical Filter, 1981 Flow Augmentation: Montrose, Everton Reservoirs	Same as Plan 1A	Montrose Reservoir	1) STP-CAS+Guelph RBC	379	94	54	Best water quality on the Grand River and Speed River is achieved by this plan.
				2) STP-New Facilities	227	90	70	
				3) Water Supply	38	14	9	
				4) Reservoirs	65	59	57	
				5) Other Flood Prot.	1	1	1	
				6) Water Sup. Benefits	1078	107	26	
				7) Flood Prot. Benefits	27/28*	9	5	
	69% - Speed 90% - Grand	100%	51% / 57%	8) Net Benefits = (6+7) - (2+3+4+5)	774/ 775	-48	-106	

Note: Percent figures refer to % of objective achieved; except where noted the objectives are: Water Quality = meet a water quality index of 0.0 on the Grand river and on the Speed river; Water Supply = Max. Day Demand; Flood Damage Reduction = zero average annual damages.

A range of flood damage benefits is given for multi-purpose reservoirs. This range reflects variations in the assumed storage volume available in the spring to retain flood flows. Storage volumes will vary with the time of year and the operating rules used for each reservoir.

Table B.2 Summary of Preliminary Water Management Plans For A Medium Population Projection (Cont'd)
(Costs and Benefits are in Millions of 1979 Dollars)

PLAN	PLAN DESCRIPTION:			PRESENT VALUE OF BENEFITS & COSTS				NOTES
	WATER QUALITY	WATER SUPPLY	FLOOD PREVENTION	ITEM	DISCOUNT RATE			
					0%	6%	10%	
10	Same as Plan 1A 28% - Speed 23% - Grand	Same as Plan 1A 100%	St. Jacobs Single-Purpose Reservoir Dykes in New Hamburg 49% / 50%	1) STP-CAS+Guelph RBC	379	94	54	
				2) STP-New Facilities	77	30	23	
				3) Water Supply	38	14	9	
				4) Reservoirs	26	25	24	
				5) Other Flood Prot.	1	1	1	
				6) Water Sup. Benefits	1078	107	26	
				7) Flood Prot. Benefits	25/26*	8	5	
				8) Net Benefits = (6+7) - (2+3+4+5)	961/ 962	45	-26	
11	Same as Plan 1A 28% - Speed 32% - Grand	Same as Plan 1A 100%	Wallenstein Reservoir Single-Purpose Reservoirs at: Salem St. Jacobs Freeport Dykes in New Hamburg 61%	1) STP-CAS+Guelph RBC	379	94	54	Single-purpose or dry reservoirs are used for flood control only. Reservoirs remain dry during non-flood periods.
				2) STP-New Facilities	77	30	23	
				3) Water Supply	38	14	9	
				4) Reservoirs	126	116	111	
				5) Other Flood Prot.	1	1	1	
				6) Water Sup. Benefits	1078	107	26	
				7) Flood Prot. Benefits	30	9	6	
				8) Net Benefits = (6+7) - (2+3+4+5)	866	49	– 112	

Note: Percent figures refer to % of objective achieved; except where noted the objectives are: Water Quality = meet a water quality index of 0.0 on the Grand river and on the Speed river; Water Supply = Max. Day Demand; Flood Damage Reduction = zero average annual damages.

* A range of flood damage benefits is given for multi-purpose reservoirs. This range reflects variations in the assumed storage volume available in the spring to retain flood flows. Storage volumes will vary with the time of year and the operating rules used for each reservoir.

Table B.3 Description of Water Management Objectives

OBJECTIVE	WATER QUALITY	WATER SUPPLY	FLOODING
DESCRIPTION	Maintain adequate dissolved oxygen levels with minimum values never falling below 4.0 mg/L.	Satisfy average and maximum day demand.	Eliminate or reduce average annual flood damages.
MEASUREMENT OF % CHANGE	% Reduction in water quality D.O. index. This index is a function of non-compliance with the provincial water quality objectives, frequency of violation in any one month and length of stream in violation.	% Satisfaction of water demand.	% Reduction in average annual damages.

B.2 Evaluation and Selection of Water Management Plans

The next step after creating the twenty-six water management plans was the selection of the preferred plans. This was done in two stages: the first stage consisted of a preliminary screening of the plans to reduce the twenty-six plans to a more manageable number and the second stage consisted of selecting from this reduced number of plans, one or more preferred plans.

The preliminary screening process involved a series of evaluations which eliminated less optimal plans from further consideration. Each plan was evaluated in terms of how well it achieved the study objectives, costs and environmental and social impacts. This evaluation process reduced the number of plans to four main plans.

In the second stage, evaluations for the selection of the preferred plan were first carried out by the technical members of the basin study team and the public consultation working groups (Appendix A). The study team narrowed the plan selection from four to two preferred plans by a voting and discussion process. Similarly, each of the four public consultation working groups selected a preferred plan.

The results from the study team and the public consultation working groups were then submitted to the Grand River Implementation Committee for a final selection. After a detailed review of the four main plans and their various options, the committee identified a single plan as the preferred plan to meet the water management needs of the basin.

The following sections describe the preliminary screening and final selection process in more detail. A flow diagram, Figure B.1 describes the evaluation process and the interaction among the various groups.

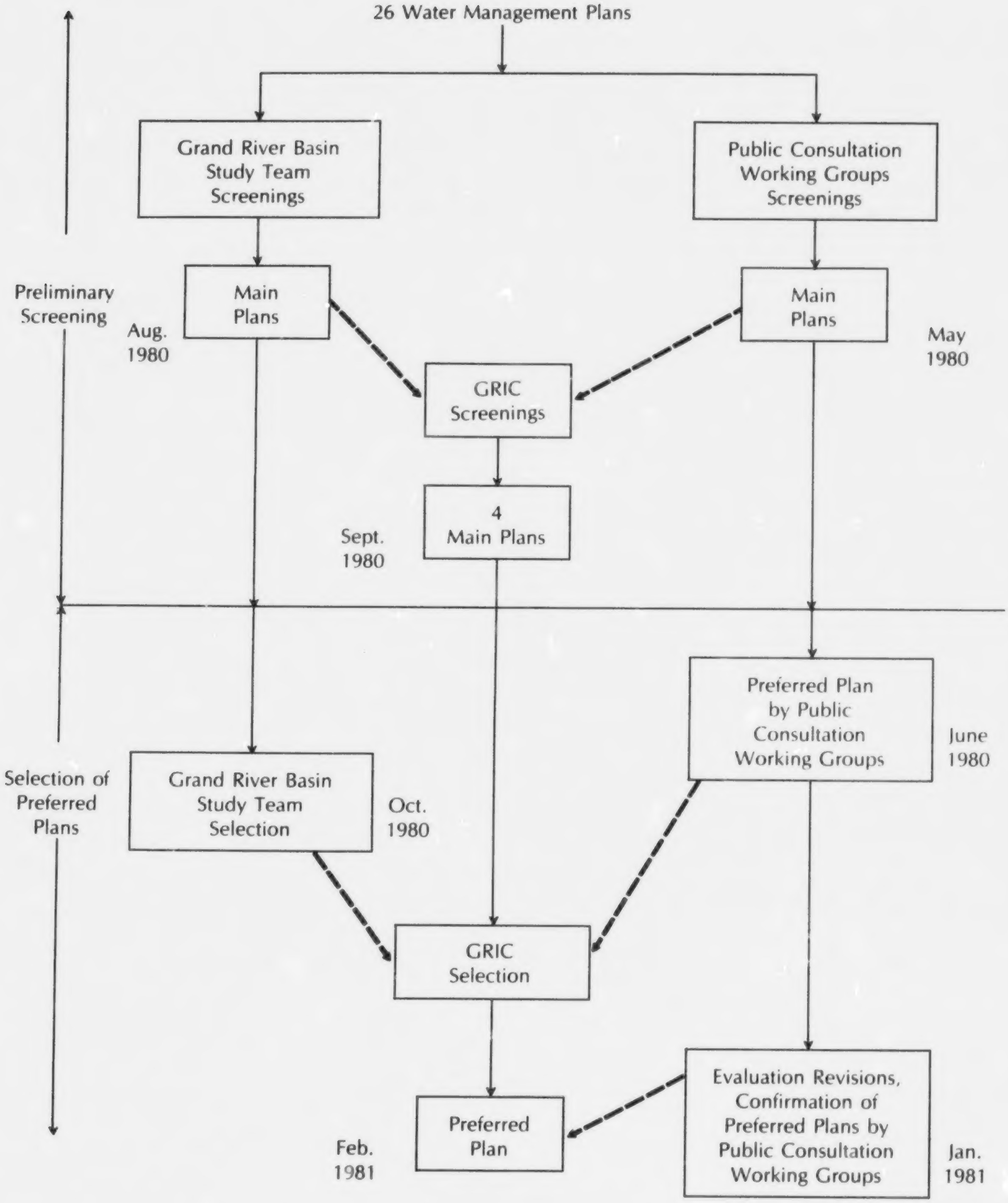

26 Water Management Plans
Grand River Basin Study Team Screenings
Public Consultation Working Groups Screenings
Preliminary Screening
Main Plans
Aug. 1980
Main Plans
May 1980
GRIC Screenings
4 Main Plans
Sept. 1980
Preferred Plan by Public Consultation Working Groups
June 1980
Selection of Preferred Plans
Grand River Basin Study Team Selection
Oct. 1980
GRIC Selection
Evaluation Revisions, Confirmation of Preferred Plans by Public Consultation Working Groups
Preferred Plan
Feb. 1981
Jan. 1981

Fig. B.1 **A flow diagram describing the evaluation process used in the selection of the preferred plan**

B.2.1 Preliminary Screening

Study Team Evaluation

The initial preliminary screening was carried out using an evaluation matrix which compared plan costs, environmental and social impacts and how satisfactorily each plan fulfilled the objectives. The details of this process are described in Appendix B.3 and the results are summarized on Table B.4. The matrix process eliminated seven plans, reducing the viable number of plans from twenty-six to eighteen plans. In a series of meetings, the basin study team evaluated the matrix results and weighed the pros and cons of each plan.

As a result of these meetings, an additional four plans were eliminated (plans 8B, 9A, 2D and 2C) and two plans (plans 1C and 1F) were incorporated into plan 1A. The reasons for eliminating the four plans are summarized in Table B.4.

Table B.4 Summary of Preliminary Screening by the Basin Study Team and GRIC

Plan	Accepted	Rejected	Incorp. With 1A	Reasons
1A	X			Meets all objectives with minimum social and environmental impacts.
1B		X		Salem reservoir only reduces flood damages 28 to 36% — rates only fair in meeting objective.
1C			X	Flood proofing by itself only offers limited flood reduction. However, flood proofing will be included in general flood reduction package to be applied to all plans.
1D		X		No flood damage reduction.
1E		⊗		Cost of land acquisition by itself is too expensive. However, land acquisition will be included in general flood reduction package to be applied in specific instances where it is the most economic solution.
1F			X	Water conservation will be included in plan 1A.
1G	X			The Everton reservoir can provide the highest water quality in the Speed river below Guelph. It will also augment the Arkell recharge water supply system for the City of Guelph.

O Rejected by evaluation matrix results
X Decision of study team and GRIC

Table B.4 (Continued)

Plan	Accepted	Rejected	Incorp. With 1A	Reasons
1H		⊗		Ranks poor in meeting flood reduction objective. The Nithburg reservoir is not effective in reducing flood damage on the Grand river. The Nithburg reservoir will be reviewed for its effect on the Nith river.
1i			X	The concept of Montrose reservoir land purchase has been expanded to include the optimum (Montrose or other) reservoir. Also, if reservoir is not needed in the future, the land can be sold.
2A	X			Meets all objectives — incorporated with plan 2B.
2B	X			
2C		X		Inefficient in flood protection.
2D		X		The Mannheim recharge scheme will provide water to Kitchener-Waterloo area at a cheaper rate than this plan (pipeline from Montrose reservoir). However, this scheme provides an alternative if the Mannheim scheme does not prove feasible.
2E	X			Will be considered as a single-purpose reservoir if it is more effective than the St. Jacobs single-purpose reservoir.
3		⊗		Poor flood reduction.
4		X		Less flood protection at a greater cost than the Montrose reservoir.
5		⊗		Poor flood damage reduction, high environmental and social impact.

O Rejected by evaluation matrix results
X Decision of study team and GRIC

Table B.4 (Continued)

Plan	Accepted	Rejected	Incorp. With 1A	Reasons
6	X			While the pipeline is extremely expensive, it has a minimum environmental and social impact. In addition, it has been a historical alternative.
7A		⊗		Water quality constraints limit urban growth
7B		⊗		Allows water quality to degrade, water supply constraints limit urban growth.
8A			X	No flood damage reduction; water conservation incorporated in plan 1A.
8B		X		Water conservation objectives unrealistic.
9A			X	The option of maintaining existing water quality conditions but allowing no degradation will be examined in plan 1.
9B		X		The effect of increasing water quality in the Grand river and the Speed rivers will be examined in plans 1 and 2.
10	X			St. Jacobs as a single-purpose reservoir is almost as efficient as a Montrose reservoir in reducing flood damages.
11		⊗		High social and environmental impacts — costly.

O Rejected by Evaluation Matrix Results
X Decision of study team and GRIC

Public Consultation Working Groups' Preliminary Screenings

In a series of meetings, the four public consultation working groups selected ten plans (1A, 1C, 1E, 2A, 2B, 2C, 2D, 6, 8, and 9B) for further study and suggested eight additional options to be included with the preferred plans. The plans and additional variations required are shown in Table B.5. This was an informal screening held prior to the screening by the study team. Several of the suggestions made by the working groups to the study team were incorporated into the preliminary plans prior to screening by the study team.

For the preliminary screening, the protection of Montrose reservoir lands, plan 1i was not an option and therefore, the working groups did not react to it. Plan 1i (later called plan A4), was formulated after the identification of preferred plans by the working groups. However, they were given an opportunity to confirm their original selections in a later meeting held in January, 1981 prior to GRIC's final selection.

Table B.5 Preliminary Screening by Public Consultation Working Groups

Upper:	**Preferred Plans** Plan 1A with Salem reservoir Plan 1A — calculate cost benefit of various flow augmentation management techniques using the existing reservoir system **Additions to Plans** flood damage reduction: — combine channelization and dyking, flood proofing, floodplain and wetland acquisition water quality: — improve sewage treatment, provide urban and rural runoff controls water supply: — increase supply by using groundwater aquifers rather than reservoirs or pipelines
Mid-Upper:	**Preferred Plans** Plans 1A, 8, 1E, 6, 2B, 1C **Additions to Plans** Plan 1A with water conservation Plan 1A with sewage treatment as in plan 8
Mid-Lower:	**Preferred Plans** Plan 1A Plan 1E — investigate social and environmental benefits gained from floodplain acquisition Plans 2B and 2C — with some reservations concerning social impacts re: Montrose reservoir **Additions to Plans** Plan 1E with Nithburg reservoir and water conservation reservoirs at Salem and Everton Reservoir at Ayr with pipeline to Kitchener-Waterloo Enlarge Shand dam Plan 1A with floodplain acquisition and water conservation Incorporate flood proofing with preferred plans
Lower:	**Preferred Plans** Plans 1A, 2A, 2B, 2C, 2E, 6, 8 and 9B **Additions to Plans** Plan 1A — add channelization and dyking or flood proofing at Cayuga

GRIC Preliminary Screenings

The Grand River Implementation Committee then reviewed the plans recommended for further evaluation by the study team and the four public consultation working groups. In discussion sessions, GRIC eliminated three additional plans (1B, 1D and 9B). Two plans (8A and 9A) were incorporated with plan 1A. Plan 9A had been previously rejected by the study team.

Summary of Preliminary Screening

Based on the preliminary screening results from the basin study team and public consultation working groups, four main plans evolved. Selected features of the previous twenty-six plans were combined as options of the four plans. A brief description of each plan and its reference to the previous twenty-six plans is given in the following table.

Main Plan	Description	Incorporates Features of the Following Plans
A	Dykes and channelization, advanced sewage treatment, local sources of water supply.	1A, 1C, 1F, 1i, 1G, 8A
B	Montrose reservoir, advanced sewage treatment, local sources of water supply.	2A, 2B, 1G, 1F, 8A
C	Dry reservoir for flood control advanced sewage treatment, local sources of water supply.	2E, 10
D	Lake Erie pipeline, advanced sewage treatment, dykes and channelization.	6

A summary of the plans and their options illustrating costs and benefits for a low low, low and high population projection is shown in Tables B.6, B.7 and B.8. Chapter 10 describes plan costs and benefits for a medium population projection.

Table B.6 Summary Table of Cos nd Benefits For Main Plans — Low Low Population Projection

(Millions of 1979 Dollars)

PLAN	PLAN DESCRIPTION:			PRESENT VALUE OF BENEFITS & COSTS			
	WATER QUALITY	WATER SUPPLY	FLOOD DAMAGE REDUCTION	ITEM	DISCOUNT RATE		
					0%	6%	10%
A Option 1	Sewage Treatment: Kitchener - Nitrification, Filtration 1981 Guelph - Chemical Treatment and Multi-Media Filtration 1981 28% - Speed 23% - Grand	Ground Water: Cambridge, Guelph Surface Water: Kitchener-Waterloo 2001 Cambridge connect to Kitchener-Waterloo 2021 100%	Dykes and Channelization: Preston, Galt, Paris, Brantford, Dunnville, Caledonia, New Hamburg 91%	1) STP-CAS + Guelph RBC 2) STP-New Facilities 3) Water Supply 4) Reservoirs 5) Other Flood Prot. 6) Water Sup. Benefits 7) Flood Prot. Benefits 8) Net Benefits = (6 + 7) - (2 + 3 + 4 + 5)	260 45 26 0 25 130 46 80	75 24 8 0 24 5 14 -37	46 20 4 0 23 -4 9 -42
A Option 2	Same as Plan A, Option 1 28% - Speed 23% - Grand	Ground Water: Guelph Surface Water: Kitchener-Waterloo 1996 Cambridge connects to Kitchener-Waterloo 1991 100%	Same as Plan A Option 1 91%	1) STP-CAS + Guelph RBC 2) STP-New Facilities 3) Water Supply 4) Reservoirs 5) Other Flood Prot. 6) Water Sup. Benefits 7) Flood Prot. Benefits 8) Net Benefits = (6 + 7) - (2 + 3 + 4 + 5)	260 45 27 0 25 127 46 76	75 24 8 0 24 4 14 -38	46 20 4 0 23 -4 9 -42
A Option 3	Same as Plan A Option 1 Flow Augmentation on Speed River from Everton Reservoir 69% - Speed 23% - Grand	Same as Plan A Option 1 100%	Same as Plan A Option 1 91%	1) STP-CAS + Guelph RBC 2) STP-New Facilities 3) Water Supply 4) Reservoirs 5) Other Flood Prot. 6) Water Sup. Benefits 7) Flood Prot. Benefits 8) Net Benefits = (6 + 7) - (2 + 3 + 4 + 5)	260 45 26 17 25 130 46 63	75 24 8 6 24 5 14 -53	46 20 4 15 23 -4 9 -57
A Option 4	Same as Plan A Option 1 Possible future augmentation on Grand River from Montrose Reservoir 28% - Speed 23% - Grand	Same as Plan A Option 1 100%	Same as Plan A Option 1 Acquire Montrose Reservoir land for possible future use 91%	1) STP-CAS + Guelph RBC 2) STP-New Facilities 3) Water Supply 4) Reservoir Land 5) Other Flood Prot. 6) Water Sup. Benefits 7) Flood Prot. Benefits 8) Net Benefits = (6 + 7) - (2 + 3 + 4 + 5)	260 45 26 0* 25 130 46 80	75 24 8 4* 24 5 14 -41	46 20 4 5* 23 -4 9 -47

Note: Percent figures refer to % of objective achieved, except where noted the objectives are: Water Quality – meet a water quality index of 0.0 on the Grand river and on the Speed river. Water Supply – Max. Day Demand. Flood Damage Reduction – zero average annual damages.

* For purposes of economic analysis it was assumed that the land acquired for the Montrose reservoir would be sold in the year 2001.

Table B.6 Summary Table of Costs and Benefits For Main Plans — Low Low Population Projection (Continued)
(Millions of 1979 Dollars)

PLAN	PLAN DESCRIPTION:			PRESENT VALUE OF BENEFITS & COSTS			
	WATER QUALITY	WATER SUPPLY	FLOOD DAMAGE REDUCTION	ITEM	DISCOUNT RATE		
					0%	6%	10%
B Option 1	Sewage Treatment: Kitchener - Nitrification. Filtration 2001 Guelph - Chemical Treatment and Multi-Media Filtration 1981 Flow Augmentation: Montrose Reservoir 28% - Speed 58% - Grand	Same as Plan A, Option 1 100%	Montrose Reservoir Dykes in New Hamburg 54% / 56%	1) STP-CAS + Guelph RBC	260	75	46
				2) STP-New Facilities	41	13	9
				3) Water Supply	26	8	4
				4) Reservoirs	46	42	41
				5) Other Flood Prot.	1	1	1
				6) Water Sup. Benefits	130	5	-4
				7) Flood Prot. Benefits	27/28*	9	5
				8) Net Benefits = (6 + 7) - (2 + 3 + 4 + 5)	43/44	-50	-54
B Option 2	Same as Plan B Option 1 28% - Speed 58% - Grand	Same as Plan A Option 1 100%	Montrose Reservoir Dykes and Channel Works same as Plan A, Option 1 96%	1) STP-CAS + Guelph RBC	260	75	46
				2) STP-New Facilities	41	13	9
				3) Water Supply	26	8	4
				4) Reservoirs	46	42	41
				5) Other Flood Prot.	25	24	23
				6) Water Sup. Benefits	130	5	-4
				7) Flood Prot. Benefits	48	15	9
				8) Net Benefits = (6 + 7) - (2 + 3 + 4 + 5)	40	-67	-72
C Option 1	Same as Plan A, Option 1 28% - Speed 23% - Grand	Same as Plan A Option 1 100%	St. Jacobs Single-Purpose Reservoir Dykes in New Hamburg 49% / 50%	1) STP-CAS + Guelph RBC	260	75	46
				2) STP-New Facilities	45	24	20
				3) Water Supply	26	8	4
				4) Reservoirs	26	25	24
				5) Other Flood Prot.	1	1	1
				6) Water Sup. Benefits	130	5	-4
				7) Flood Prot. Benefits	46	14	9
				8) Net Benefits = (6 + 7) - (2 + 3 + 4 + 5)	78	-39	-44
C Option 2	Same as Plan A, Option 1 28% - Speed 23% - Grand	Same as Plan A, Option 1 100%	Montrose Single-Purpose Reservoir 24.7 million cubic metres (20,000 acre feet) Dykes in New Hamburg 54% / 56%	1) STP-CAS + Guelph RBC	260	75	46
				2) STP-New Facilities	45	24	20
				3) Water Supply	26	8	4
				4) Reservoirs	30	28	27
				5) Other Flood Prot.	1	1	1
				6) Water Sup. Benefits	130	5	-4
				7) Flood Prot. Benefits	27/28*	9	5
				8) Net Benefits = (6 + 7) - (2 + 3 + 4 + 5)	55/56	-47	-51
C Option 3	Same as Plan A, Option 1 28% - Speed 23% - Grand	Same as Plan A, Option 1 100%	Montrose Single-Purpose Reservoir 77.7 million cubic metres (63,000 acre feet) Dykes in New Hamburg 56% / 57%	1) STP-CAS + Guelph RBC	260	75	46
				2) STP-New Facilities	45	24	20
				3) Water Supply	26	8	4
				4) Reservoirs	46	42	41
				5) Other Flood Prot.	1	1	1
				6) Water Sup. Benefits	130	5	-4
				7) Flood Prot. Benefits	27/28*	9	5
				8) Net Benefits = (6 + 7) - (2 + 3 + 4 + 5)	39/40	-61	-65
D	Same as Plan A, Option 1 28% - Speed 23% - Grand	Lake Erie Pipeline Kitchener-Waterloo, Cambridge, Brantford Ground Water: Guelph 100%	Same as Plan A, Option 1 91%	1) STP-CAS + Guelph RBC	250	73	45
				2) STP-New Facilities	40	13	8
				3) Water Supply	455	234	194
				4) Reservoirs	0	0	0
				5) Other Flood Prot.	25	24	23
				6) Water Sup. Benefits	2	-15	-11
				7) Flood Prot. Benefits	46	14	9
				8) Net Benefits = (6 + 7) - (2 + 3 + 4 + 5)**	-472	-272	-227

Note: Percent figures refer to % of objective achieved; except where noted the objectives are: Water Quality = meet a water quality index of 0.0 on the Grand river and on the Speed river; Water Supply = Max. Day Demand; Flood Damage Reduction = zero average annual damages.

* A range of flood damage benefits is given for multi-purpose reservoirs. This range reflects variations in the assumed storage volume available in the spring to retain flood flows. Storage volumes will vary with the time of year and the operating rules used for each reservoir.

** Net benefits include savings in cost Item 1 over Plan A. These savings arise due to a reduced STP hydraulic load brought about by price induced reductions in water demand.

Table B.7 Summary Table of Costs and Benefits For Main Plans — Low Population Projection
(Millions of 1979 Dollars)

PLAN	PLAN DESCRIPTION:			PRESENT VALUE OF BENEFITS & COSTS			
	WATER QUALITY	WATER SUPPLY	FLOOD DAMAGE REDUCTION	ITEM	DISCOUNT RATE		
					0%	6%	10%
A Option 1	Sewage Treatment: Kitchener - Nitrification Filtration 2006 Waterloo - Nitrification Filtration 1981 Guelph - Chemical Treatment and Multi-Media Filtration 1981 28% - Speed 23% - Grand	Ground Water: Cambridge, Guelph Surface Water: Kitchener-Waterloo 1991 100%	Dykes and Channel Works Preston, Galt, Paris, Brantford, Caledonia, Dunnville, New Hamburg 91%	1) STP-CAS + Guelph RBC 2) STP-New Facilities 3) Water Supply 4) Reservoirs 5) Other Flood Prot 6) Water Sup. Benefits 7) Flood Prot. Benefits 8) Net Benefits = (6 + 7) - (2 + 3 + 4 + 5)	269 55 32 0 25 210 46 144	77 26 12 0 24 20 14 -28	47 20 8 0 23 2 9 40
A Option 2	Same as Plan A, Option 1 28% - Speed 23% - Grand	Ground Water Guelph Surface Water Kitchener-Waterloo 1991 Cambridge connects to Kitchener-Waterloo 1986 100%	Same as Plan A Option 1 91%	1) STP-CAS + Guelph RBC 2) STP-New Facilities 3) Water Supply 4) Reservoirs 5) Other Flood Prot 6) Water Sup. Benefits 7) Flood Prot. Benefits 8) Net Benefits = (6 + 7) - (2 + 3 + 4 + 5)	269 55 28 0 25 208 46 146	77 26 11 0 24 19 14 28	47 20 7 0 23 2 9 39
A Option 3	Same as Plan A Option 1 Flow Augmentation on Speed River from Everton Reservoir 69% - Speed 23% - Grand	Same as Plan A Option 1 100%	Same as Plan A Option 1 91%	1) STP-CAS + Guelph RBC 2) STP-New Facilities 3) Water Supply 4) Reservoirs 5) Other Flood Prot 6) Water Sup. Benefits 7) Flood Prot. Benefits 8) Net Benefits = (6 + 7) - (2 + 3 + 4 + 5)	269 55 32 17 25 210 46 127	77 26 12 16 24 20 14 44	47 20 8 15 23 2 9 55
A Option 4	Same as Plan A, Option 1 Possible future augmentation on Grand River from Montrose Reservoir 28% - Speed 23% - Grand	Same as Plan A, Option 1	Same as Plan A Option 1 Acquire Montrose Reservoir land for possible future use	1) STP-CAS + Guelph RBC 2) STP-New Facilities 3) Water Supply 4) Reservoir Land 5) Other Flood Prot. 6) Water Sup. Benefits 7) Flood Prot. Benefits 8) Net Benefits = (6 + 7) - (2 + 3 + 4 + 5)	269 55 32 0* 25 210 46 144	77 26 12 4* 24 20 14 -32	47 20 8 5* 23 2 9 45

Note: Percent figures refer to % of objective achieved; except where noted the objectives are: Water Quality = meet a water quality index of 0.0 on the Grand river and on the Speed river; Water Supply = Max. Day Demand; Flood Damage Reduction = zero average annual damages.

* For purposes of economic analysis it was assumed that the land acquired for the Montrose reservoir would be sold in the year 2001.

Table B.7 Summary Table of Costs and Benefits For Main Plans — Low Population Projection (Continued)

(Millions of 1979 Dollars)

PLAN	PLAN DESCRIPTION:			PRESENT VALUE OF BENEFITS & COSTS			
	WATER QUALITY	WATER SUPPLY	FLOOD DAMAGE REDUCTION	ITEM	DISCOUNT RATE		
					0%	6%	10%
B Option 1	Sewage Treatment: Kitchener - Nitrification, Filtration Waterloo - Nitrification Filtration, 2021 Guelph - Chemical Treatment and Multi-Media Filtration 1981 Flow Augmentation: Montrose Reservoir 28% - Speed 58% - Grand	Same as Plan A, Option 1 100%	Montrose Reservoir Dykes in New Hamburg 54% / 56%	1) STP-CAS + Guelph RBC	379	94	54
				2) STP-New Facilities	68	17	10
				3) Water Supply	38	14	9
				4) Reservoirs	46	42	41
				5) Other Flood Prot.	1	1	1
				6) Water Sup. Benefits	1078	107	26
				7) Flood Prot. Benefits	27/28*	9	5
				8) Net Benefits = (6 + 7) - (2 + 3 + 4 + 5)	952/ 953	42	- 30
B Option 2	Same as Plan B, Option 1 28% - Speed 58% - Grand	Same as Plan A Option 1 100%	Montrose Reservoir Dykes and Channel Works same as in Plan A, Option 1 96%	1) STP-CAS + Guelph RBC	379	94	54
				2) STP-New Facilities	68	17	10
				3) Water Supply	38	14	9
				4) Reservoirs	46	42	41
				5) Other Flood Prot.	25	24	23
				6) Water Sup. Benefits	1078	107	26
				7) Flood Prot. Benefits	48	15	9
				8) Net Benefits = (6 + 7) - (2 + 3 + 4 + 5)	949	25	- 48
C Option 1	Same as Plan A Option 1 28% - Speed 23% - Grand	Same as Plan A Option 1 100%	St. Jacobs Single Purpose Reservoir Dykes in New Hamburg 49% / 50%	1) STP-CAS + Guelph RBC	379	94	54
				2) STP-New Facilities	77	30	23
				3) Water Supply	38	14	9
				4) Reservoirs	26	25	24
				5) Other Flood Prot.	1	1	1
				6) Water Sup. Benefits	1078	107	26
				7) Flood Prot. Benefits	25/26*	8	5
				8) Net Benefits = (6 + 7) - (2 + 3 + 4 + 5)	961/ 962	45	- 26
C Option 2	Same as Plan A Option 1 28% - Speed 23% - Grand	Same as Plan A Option 1 100%	Montrose Single Purpose Reservoir 24.7 million cubic metres (20,000 acre feet) Dykes in New Hamburg 54% / 56%	1) STP-CAS + Guelph RBC	379	94	54
				2) STP-New Facilities	77	30	23
				3) Water Supply	38	14	9
				4) Reservoirs	30	28	27
				5) Other Flood Prot.	1	1	1
				6) Water Sup. Benefits	1078	107	26
				7) Flood Prot. Benefits	27/28*	9	5
				8) Net Benefits = (6 + 7) - (2 + 3 + 4 + 5)	959/ 960	43	- 29
C Option 3	Same as Plan A Option 1 28% - Speed 23% - Grand	Same as Plan A Option 1 100%	Montrose Single Purpose Reservoir 77.7 million cubic metres (63,000 acre feet) Dykes in New Hamburg 56% / 57%	1) STP-CAS + Guelph RBC	269	77	47
				2) STP-New Facilities	55	26	20
				3) Water Supply	32	12	8
				4) Reservoirs	46	42	41
				5) Other Flood Prot.	1	1	1
				6) Water Sup. Benefits	210	20	2
				7) Flood Prot. Benefits	27/28*	9	5
				8) Net Benefits = (6 + 7) - (2 + 3 + 4 + 5)	103/ 104	- 52	- 63
D	Same as Plan A, Option 1 28% - Speed 23% - Grand	Lake Erie Pipeline Kitchener-Waterloo, Cambridge, Brantford Ground Water: Guelph 100%	Same as Plan A Option 1 91%	1) STP-CAS + Guelph RBC	252	74	45
				2) STP-New Facilities	55	26	20
				3) Water Supply	471	238	196
				4) Reservoirs	0	0	0
				5) Other Flood Prot.	25	24	23
				6) Water Sup. Benefits	47	-9	- 10
				7) Flood Prot. Benefits	46	14	9
				8) Net Benefits = (6 + 7) - (2 + 3 + 4 + 5)**	454	- 283	- 240

Note: Percent figures refer to % of objective achieved: except where noted the objectives are: Water Quality = meet a water quality index of 0.0 on the Grand river and on the Speed river: Water Supply = Max. Day Demand: Flood Damage Reduction = zero average annual damages.

* A range of flood damage benefits is given for multi-purpose reservoirs. This range reflects variations in the assumed storage volume available in the spring to retain flood flows. Storage volumes will vary with the time of year and the operating rules used for each reservoir.

** Net benefits include savings in cost item 1 over Plan A. These savings arise due to a reduced STP hydraulic load brought about by price induced reductions in water demand.

Table B.8 Summary Table of Costs and Benefits For Main Plans — High Population Projection
(Millions of 1979 Dollars)

PLAN	PLAN DESCRIPTION:			PRESENT VALUE OF BENEFITS & COSTS			
	WATER QUALITY	WATER SUPPLY	FLOOD DAMAGE REDUCTION	ITEM	DISCOUNT RATE		
					0%	6%	10%
A Option 1	Sewage Treatment: Waterloo - Nitrification, Filtration 2001 Kitchener - Nitrification, Filtration 1981 Guelph - Chemical Treatment and Multi-Media Filtration 1981 28% - Speed 23% - Grand	Ground Water: Cambridge, Guelph Surface Water: Kitchener-Waterloo 1991 Cambridge connects to Kitchener-Waterloo 2016 100%	Dykes and Channel Works Preston, Galt, Paris, Brantford, Caledonia, Dunnville, New Hamburg 91%	1) STP-CAS + Guelph RBC	449	115	66
				2) STP-New Facilities	85	32	24
				3) Water Supply	47	17	10
				4) Reservoirs	0	0	0
				5) Other Flood Prot.	25	24	23
				6) Water Sup. Benefits	2125	205	52
				7) Flood Prot. Benefits	46	14	9
				8) Net Benefits = (6 + 7) - (2 + 3 + 4 + 5)	2014	146	4
A Option 2	Same as Plan A, Option 1 28% - Speed 23% - Grand	Ground Water: Cambridge, Guelph Surface Water: Kitchener-Waterloo 1991 Cambridge connects to Kitchener-Waterloo 1986 100%	Same as Plan A, Option 1 91%	1) STP-CAS + Guelph RBC	449	115	66
				2) STP-New Facilities	85	32	24
				3) Water Supply	42	15	9
				4) Reservoirs	0	0	0
				5) Other Flood Prot.	25	24	23
				6) Water Sup. Benefits	2121	205	52
				7) Flood Prot. Benefits	46	14	9
				8) Net Benefits = (6 + 7) - (2 + 3 + 4 + 5)	2015	148	5
A Option 3	Same as Plan A, Option 1 Flow Augmentation on Speed River from Everton Reservoir 69% - Speed 23% - Grand	Same as Plan A, Option 1 100%	Same as Plan A, Option 1 91%	1) STP-CAS + Guelph RBC	449	115	66
				2) STP-New Facilities	85	32	24
				3) Water Supply	47	17	10
				4) Reservoirs	17	16	15
				5) Other Flood Prot.	25	24	23
				6) Water Sup. Benefits	2125	205	52
				7) Flood Prot. Benefits	46	14	9
				8) Net Benefits = (6 + 7) - (2 + 3 + 4 + 5)	1997	130	7
A Option 4	Same as Plan A, Option 1 Possible future augmentation on Grand River from Montrose Reservoir 28% - Speed 23% - Grand	Same as Plan A, Option 1 100%	Same as Plan A, Option 1 Acquire Montrose Reservoir land for possible future use 91%	1) STP-CAS + Guelph RBC	449	115	66
				2) STP-New Facilities	85	32	24
				3) Water Supply	47	17	10
				4) Reservoir Land	0*	4*	5*
				5) Other Flood Prot.	25	24	23
				6) Water Sup. Benefits	2125	205	52
				7) Flood Prot. Benefits	46	14	9
				8) Net Benefits = (6 + 7) - (2 + 3 + 4 + 5)	2014	142	-1

Note: Percent figures refer to % of objective achieved; except where noted the objectives are: Water Quality = meet a water quality index of 0.0 on the Grand river and on the Speed river; Water Supply = Max. Day Demand; Flood Damage Reduction = zero average annual damages.

* For purposes of economic analysis it was assumed that the land acquired for the Montrose reservoir would be sold in the year 2001.

Table B.8 Summary Table of Costs and Benefits For Main Plans — High Population Projection (Continued)

(Millions of 1979 Dollars)

PLAN	PLAN DESCRIPTION:			PRESENT VALUE OF BENEFITS & COSTS			
	WATER QUALITY	WATER SUPPLY	FLOOD DAMAGE REDUCTION	ITEM	DISCOUNT RATE		
					0%	6%	10%
B Option 1	Sewage Treatment: Waterloo - Nitrification, Filtration 2021 Kitchener - Nitrification, Filtration, 2001 Guelph - Chemical Treatment and Multi-Media Filtration 1981 Flow Augmentation: Montrose Reservoir 28% - Speed 58% - Grand	Same as Plan A, Option 1 100%	Montrose Reservoir Dykes in New Hamburg 54% / 56%	1) STP-CAS + Guelph RBC	449	115	66
				2) STP-New Facilities	76	20	12
				3) Water Supply	47	17	10
				4) Reservoirs	46	42	41
				5) Other Flood Prot.	1	1	1
				6) Water Sup. Benefits	2125	205	52
				7) Flood Prot. Benefits	27/28*	9	5
				8) Net Benefits = (6 + 7) - (2 + 3 + 4 + 5)	1982/ 1983	134	−7
B Option 2	Same as Plan B, Option 1 28% - Speed 58% - Grand	Same as Plan A Option 1 100%	Montrose Reservoir Dykes and Channel Works same as in Plan A, Option 1 96%	1) STP-CAS + Guelph RBC	449	115	66
				2) STP-New Facilities	76	20	12
				3) Water Supply	47	17	10
				4) Reservoirs	46	42	41
				5) Other Flood Prot.	25	24	23
				6) Water Sup. Benefits	2125	205	52
				7) Flood Prot. Benefits	27/28*	9	5
				8) Net Benefits = (6 + 7) - (2 + 3 + 4 + 5)	1958/ 1959	111	−29
C Option 1	Same as Plan A. Option 1 28% - Speed 23% - Grand	Same as Plan A. Option 1 100%	St. Jacobs Single-Purpose Reservoir Dykes in New Hamburg 49% / 50%	1) STP-CAS + Guelph RBC	449	115	66
				2) STP-New Facilities	85	32	24
				3) Water Supply	47	17	10
				4) Reservoirs	26	25	24
				5) Other Flood Prot.	1	1	1
				6) Water Sup. Benefits	2125	205	52
				7) Flood Prot. Benefits	25/26*	8	5
				8) Net Benefits = (6 + 7) - (2 + 3 + 4 + 5)	1991/ 1992	138	−2
C Option 2	Same as Plan A. Option 1 28% - Speed 23% - Grand	Same as Plan A. Option 1 100%	Montrose Single-Purpose Reservoir 24.7 million cubic metres (20,000 acre feet) Dykes in New Hamburg 54% / 56%	1) STP-CAS + Guelph RBC	449	115	66
				2) STP-New Facilities	85	32	24
				3) Water Supply	47	17	10
				4) Reservoirs	30	28	27
				5) Other Flood Prot.	1	1	1
				6) Water Sup. Benefits	2125	205	52
				7) Flood Prot. Benefits	27/28*	9	5
				8) Net Benefits = (6 + 7) - (2 + 3 + 4 + 5)	1989/ 1990	136	−5
C Option 3	Same as Plan A. Option 1 28% - Speed 23% - Grand	Same as Plan A. Option 1 100%	Montrose Single-Purpose Reservoir 77.7 million cubic metres (63,000 acre feet) Dykes in New Hamburg 56% / 57%	1) STP-CAS + Guelph RBC	449	115	66
				2) STP-New Facilities	85	32	24
				3) Water Supply	47	17	10
				4) Reservoirs	46	42	41
				5) Other Flood Prot.	1	1	1
				6) Water Sup. Benefits	2125	205	52
				7) Flood Prot. Benefits	27/28*	9	5
				8) Net Benefits = (6 + 7) - (2 + 3 + 4 + 5)	1973/ 1974	122	−19
D	Same as Plan A. Option 1 28% - Speed 23% - Grand	Lake Erie Pipeline Kitchener-Waterloo, Cambridge, Brantford Ground Water: Guelph 100%	Same as Plan A, Option 1 91%	1) STP-CAS + Guelph RBC	409	108	63
				2) STP-New Facilities	80	32	24
				3) Water Supply	576	279	230
				4) Reservoirs	0	0	0
				5) Other Flood Prot.	25	24	23
				6) Water Sup. Benefits	1870	165	35
				7) Flood Prot. Benefits	46	14	9
				8) Net Benefits = (6 + 7) - (2 + 3 + 4 + 5)**	1235	−156	−233

Note: Percent figures refer to % of objective achieved; except where noted the objectives are: Water Quality = meet a water quality index of 0.0 on the Grand river and on the Speed river; Water Supply = Max. Day Demand; Flood Damage Reduction = zero average annual damages.

* A range of flood damage benefits is given for multi-purpose reservoirs. This range reflects variations in the assumed storage volume available in the spring to retain flood flows. Storage volumes will vary with the time of year and the operating rules used for each reservoir.

** Net benefits include savings in cost Item 1 over Plan A. These savings arise due to a reduced STP hydraulic load brought about by price induced reductions in water demand.

B.2.3 Selection of Preferred Plan

Utilizing the results of the prior evaluations, the Grand River Implementation Committee, through a series of discussions and voting procedures, identified a preferred plan.

The study team plus invited technical experts from other basin sub-committees, reviewed the four main plans and submitted formal written responses ranking the plans and their four variations. The voting results were analyzed on the basis of two groupings:

- Grand River Basin Study Team (Appendix A and G)
- Grand River Basin Study Team plus invited technical experts from other committees (members listed in Table B.9).

The technical experts were familiar with the basin study and had served on one or more of the study's technical sub-committees. The voting results listed in Table B.10 were analysed using four different voting procedures; the Simple Plurality scheme, the Borda Count, Pair Wise Wins and the Copeland Score (Ref. Tech. Report No. 25).

The voting analysis narrowed the selection to two main plans; A and B, and four variations of these plans; A1, A2, A4 and B2. For both groups, plans A1, A2, A4 and B2 were almost equally ranked. The study team by itself appeared to prefer plan A4 over plan B2, while the larger group's preference shifted slightly from plan A4 to plan B2. The voting indicated that the basin water managers tended to favour the Montrose dam option, plan B2, because it offered a more reliable and secure water management system. Other members more removed from the immediate management of the river generally opted for plan A (1, 2 or 4) with its lower cost and reduced social and environmental impacts.

Table B.9 Enlarged Study Team

Members of basin study team plus the following invited members:

M. Fortin,
Systems Economist (Basin Study),
Water Resources Branch,
Ministry of the Environment

B. Mitchell,
Faculty of Environmental Studies,
Dept. of Geography,
University of Waterloo

U. Sibul, Head,
Resource Assessment Group,
Water Resources Branch,
Ministry of the Environment

R. Wilson,
General Manager,
Brantford Public Utilities Commission,
City of Brantford

E. McBean,
Faculty of Engineering,
Dept. of Civil Engineering,
University of Waterloo

J. Sanvido,
Superintendent of Water Pollution and Water Works,
City of Guelph

D. Weatherbe, Head,
River Systems Unit,
Water Resources Branch,
Ministry of the Environment

Note: Members of the basin study team are listed in Appendix A.

Table B.10 Selection of the Preferred Plans by The Basin Study Team using Various Voting Techniques

Voting Results From Study Team Only

Voting Scores

Plans

Voting Method	A1.2	A4	B1	B2	C1	C2	C3	D
Plurality	3	5	1	4				
Borda	56	59	23	51	12	11	0	0
Pair Wise Wins	6	7	4	5	3	2	0	0
Copeland	5	7	1	3	-1	-3	-6	-6
Overall ranking	2	1		3				

Voting Results From Enlarged Study Team

Voting Scores

Plans

Voting Method	A1.2	A4	B1	B2	C1	C2	C3	D
Plurality	5	6	1	6				
Borda	93	88	42	94	15	22	4	0
Pair Wise Wins*	6	6	4	5	2	3	1	0
Copeland	5	5	1	3	-3	-1	-5	-7
Overall ranking		1		1				

* If a clear majority is not indicated in pair wise voting (as in this case) then the Borda Count results are recommended for use in place of Pair Wise Wins.

Public Consultation Working Group Selections

In June, 1980, the public consultation working groups made their final plan selections. These plans were chosen from the plans which appeared viable after the preliminary screening exercise undertaken by them and prior to the study team's selection. Three of the four working groups selected plan A as their final choice. The fourth group, representing the lower region of the basin, selected plan B as its first choice. Table B.11 summarizes the plan selections and Technical Report Nos. 25 and 43 discuss their choices in more detail. The plan numbers are given in their original numerical classification as well as their equivalent main plan alphabetical classification.

After the plan selection of June, 1980, a new plan 1i (later called Plan A4) was added and evaluated by GRIC. In addition, several technical revisions altered the effectiveness of various plans.

The changes occurring principally in the water quality area, were due to corrections and improvements in the simulation models. A meeting with the public consultation working groups was held in January, 1981 to inform them of the changes. The original plan selections were reconfirmed. However, two of the three groups favouring plan A1 (upper and mid-upper groups) did not favour plan A4's preservation of the Montrose reservoir lands.

Table B.11 Preferred Plan Selections by Public Consultation Working Groups

Public Consultation Working Groups	Preferred Plan		Comments
	Original Classification	Main Plan Classification	
Upper	1F	A1	— incorporate planned floodplain acquisition with plan
Mid-Upper	1A	A1	— incorporate urban and rural stormwater management — improve surface water quality monitoring, particularly with respect to toxic substances — improve ground water quality monitoring network — introduce water conservation — review assumptions on a regular basis — need a co-ordinating body for plan implementation
Mid-Lower	1A, 1F 1G	A1, A2 A3	
Lower	2B 2A 2C (in order of preference)	B2 B1	— Montrose Reservoir required to augment flows for water quality and recreational purposes

GRIC Selection

GRIC reviewed the results of the study team and the public consultation working groups and then carried out a lengthy examination of the pros and cons of each plan (Chapters 9 and 10). An initial voting analysis was carried out to provide a basis for further discussion (Table B.12). Following further evaluations of the merits and disadvantages of each plan, the Grand River Implementation Committee identified plan A4 as the preferred plan to guide water management discussions in the basin.

The reasons for this selection are discussed in detail in Chapter 12.

Table B.12 GRIC Voting Results of February, 1981

Voting Procedure	Water Management Plans			
	A1	A4	B2	C, D
Plurality	3	2	4	0
Borda	16	19	19	0
Pair Wise Wins	1	2	3	0
Copeland	1	1	3	-3

Wins and ties are underlined

B.3 Evaluation Matrix

An evaluation matrix was used by the basin study team in carrying out an initial screening of the twenty-six water management plans (Appendix B.2). This matrix, shown on Table B.18, was derived by assessing each plan in terms of:

a) achievement of the study objectives
b) costs
c) environmental impacts
d) social impacts.

The objectives and costs were assessed using quantitative data related to a common grading system. The intangible parameters (environmental and social impacts) were graded based on the results of a questionnaire which was analyzed using a multi-criteria method called fuzzy set analysis (Ref. Tech. Report No. 25).

Each plan's parameters were then compared to the corresponding parameters of other plans through the same multi-criteria method. This method enabled the plans to be classified as very good, good, fair or poor. A description of the grading system, formation of the matrix and evaluation of the plans is provided in the following section.

B.3.1 Grading of Objectives

Flood Damage Reduction

The effectiveness of each plan in reducing flood damages was measured using the average annual flood damages calculated for each plan (Appendix F.1). The grading system was established by dividing the total average annual damages of approximately $1,000,000 equally among four grades; very good, good, fair and poor. This assumes, for example, that any plan that does not reduce average annual flood damages by 25 percent should be considered poor in terms of meeting the flood damage reduction objective.

The grading system and corresponding plan groupings are shown in Table B.13.

Water Quality Improvement

The effectiveness of each plan for improving water quality was measured by the dissolved oxygen water quality severity index (Appendix E.1). The grading of the water quality achieved by each plan was based on available fish toxicity information (Ref. Tech. Report No. 13) and is presented in Table B.14.

Table B.13 Evaluation Grading System for Flood Damage Reduction

Grading	Average Annual Flood Damages (in thousands of dollars)	Plan Ranking
Very Good	0 - 250	1A, 1E, 1F, 1G, 1i 2B, 2C, 6, 9A
Good	250 - 500	2A, 2D, 2E, 4, 9B, 10, 11
Fair	500 - 750	
Poor	750 - 1,000	1B, 1C, 1D, 1H, 3, 5, 7A, 7B, 8A, 8B

Table B.14 Evaluation Grading System for Water Quality

Grading	Description	Dissolved Oxygen Water Quality Index — Grand River	Plan Ranking for Water Quality on the Grand River	Dissolved Oxygen Water Quality Index — Speed River	Plan Ranking for Water Quality on the Speed River
Very Good	Meets dissolved oxygen criteria for warm-water fish 100 percent of the time.	0+		0+	
Good	Meets existing dissolved oxygen criteria 95 per cent of the time. Dissolved oxygen does not fall below 3.5 mg/L. Conditions equal to background conditions upstream of Waterloo or Guelph.	0 - 17	2A, 2B, 2C, 2D, 9B	0 - 9	1G, 11, 9B
Fair	Improves existing dissolved oxygen level.	17 - 40	1A, 1B, 1C, 1D, 1E, 1F, 1G, 1H, 1i, 2E, 3, 6, 8A, 8B, 10, 5, 11, 4		1A, 1B, 1C, 1D, 1E, 1F, 1H, 1i, 2A, 2B, 2C, 2D, 2E, 3, 4, 5, 6, 8A, 8B, 9, 10
Poor	Existing conditions.	40 - 63	7A, 7B, 9A	20 - 49	7A, 7B, 9A

Water Supply Benefits

Since the water supply objective is met 100 percent of the time for all plans, an evaluation of how well each plan meets the objectives is measured by the water supply benefits accrued. Benefits are measured using the consumer surplus technique outlined in Appendix C.2.

As with grading of each for flood damage reduction, the grading system for water supply benefits was established by dividing the highest water supply benefit achieved by a plan equally among the four gradations of very good, good, fair and poor. The gradings and plan evaluations are shown in Table B.15.

Water Management Plan Costs

Total plan costs were used to evaluate the adequacy of each plan in achieving the objectives at a minimum cost. Total costs include advanced sewage treatment costs, water supply costs, and reservoir and channelization costs.

The grading system was established by dividing the highest total cost for a plan equally among four gradations. This assumes, for example, that those plans with less than 25 percent of the highest total cost should be considered very good. The grading and evaluations are given in Table B.16.

Table B.15 Evaluation Grading System for Water Supply Benefits

Grading	Water Supply Benefits (Present value in millions of 1979 dollars at 6% Discount)	Plan Ranking
Very Good	75 - 100	1A, 1B, 1C, 1D, 1E, 1G, 1H, 1i, 2A, 2B, 2C, 2E, 3, 4, 9A, 9B, 10, 11
Good	50 - 75	1F, 2D, 5, 6, 8A
Fair	25 - 50	7B, 8B
Poor	0 - 25	7A

Table B.16 Evaluation Grading System For Plan Costs

Grading	Total Cost (Present value in millions of 1979 dollars at 6% Discount)	Plan Ranking
Very Good	0 - 133	1A, 1B, 1C, 1D, 1F, 1G, 1H, 1i, 2A, 2B, 2C, 2E, 3, 4, 7A, 7B, 8A, 8B, 9A, 10
Good	133 - 266	2D, 5, 9B, 11
Fair	266 - 399	6
Poor	399 - 532	1E

Environmental and Social Impacts

Since many environmental and social impacts are nonquantitative, they are difficult to grade objectively. To overcome this problem, the basin study designed a questionnaire which was completed by the basin study team (Appendix B.2). The responses of the questionnaire were compared using a fuzzy set analysis. The social and environmental impacts of each plan were then ranked (Ref. Tech. Report No. 25).

Eight parameters were used to evaluate environmental and social impacts. The parameters used in the environmental evaluation were:

a) land habitat (animals and plants)
b) aesthetics (land based).

The parameters used in the social impact analysis were:

a) agricultural land permanently removed
b) agricultural land with reduced flood damage
c) households permanently relocated
d) community ties
e) transportation
f) recreation.

The results of the analysis and plan grading are shown in Table B.17. For comparison purposes, the grading of the plans by the basin study team are presented with the grading of the plans by the public consultation working groups (Appendix B.2). The results from these two groups were similar, since their ranking of each plan did not differ by more than one gradation.

Table B.17 Plan Ranking for Environmental and Social Impacts

Grading	Plan Ranking for Environmental Impacts		Plan Ranking for Social Impacts	
	Basin Study Team	Public Consultation Working Groups*	Basin Study Team	Public Consultation Working Groups*
Very Good	1C (1A, 1F, 1D, 1i, 6, 7A, 7B, 8A, 8B 9A)	1A, 1F, 8A, 8B 1C, 6	1F 1A	1A, 1F 6 1C 8A, 8B
Good	1B 1E 2E 10	1B 1D, 1E, 7A, 7B, 9A	1B, 1H, 1i, 6 3, 2E 8A, 1C, 8B	9A 1D 7A, 7B 2E
Fair		2E	7B, 7A, 9A 4 1G 1D 2C, 2B 2D, 2A 9B 10	1B 1E 1G 3 2C, 2B, 4, 9B 2A, 2B
Poor	1G, 1H 2A, 2B, 2C, 2D, 3, 4, 5, 9B, 11	1G 2A, 2B, 2C, 2D, 9B 3, 4, 5	1E 11 5	5

* Plans 10, 11, 1i and 1H were not evaluated by the public consultation working groups at the time of the questionnaire.

Table B.18 Plan Evaluation Matrix

	Effectiveness in Meeting Plan Objectives			Plan Impact				Preliminary** Plan Screening	
Plan*	Flood Damage Reduction (1)	Maintain an Adequate Water Quality (2)	Provide an Adequate Water Supply (3)	Costs (4)	Environmental Impact (5)	Social Impact (6)	Plan Evaluation by Fuzzy Set Analysis (7)	In (8)	Out (9)
1A	Very Good	Fair-Speed R. Fair-Grand R.	Very Good	Very Good	Very Good	Very Good	Very Good	X	
1B	Poor	Fair-Speed R. Fair-Grand R.	Very Good	Very Good	Good	Good	Good	X	
1C	Poor	Fair-Speed R. Fair-Grand R.	Very Good	Very Good	Very Good	Good	Good	X	
1D	Poor	Fair-Speed R. Fair-Grand R.	Very Good	Very Good	Very Good	Fair	Good	X	
1E	Very Good	Fair-Speed R. Fair-Grand R.	Very Good	Poor	Good	Good	Fair		X
1F	Very Good	Fair-Speed R. Fair-Grand R.	Good	Very Good	Very Good	Very Good	Very Good	X	
1G	Very Good	Good-Speed R. Fair-Grand R.	Very Good	Very Good	Poor	Fair	Good	X	
1H	Poor	Fair-Speed R. Fair-Grand R.	Very Good	Very Good	Poor	Good	Fair		X
1i	Very Good	Fair-Speed R. Fair-Grand R.	Very Good	Very Good	Very Good	Good	Very Good	X	
2A	Good	Fair-Speed R. Good-Grand R.	Very Good	Very Good	Poor	Fair	Good	X	
2B	Very Good	Fair-Speed R. Good-Grand R.	Very Good	Very Good	Poor	Fair	Good	X	
2C	Very Good	Fair-Speed R. Good-Grand R.	Very Good	Very Good	Poor	Fair	Good	X	
2D	Good	Fair-Speed R. Good-Grand R.	Very Good	Good	Poor	Fair	Good	X	
2E	Good	Fair-Speed R. Fair-Grand R.	Very Good	Very Good	Good	Good	Very Good	X	
3	Poor	Fair-Speed R. Fair-Grand R.	Very Good	Very Good	Poor	Good	Fair		X
4	Good	Fair-Speed R. Fair-Grand R.	Very Good	Very Good	Poor	Fair	Good	X	
5	Poor	Fair-Speed R. Fair-Grand R.	Good	Good	Poor	Poor	Poor		X
6	Very Good	Fair-Speed R. Fair-Grand R.	Good	Fair	Very Good	Good	Very Good	X	
7A	Poor	Poor-Speed R. Poor-Grand R.	Poor	Very Good	Very Good	Fair	Poor		X
7B	Poor	Poor-Speed R. Poor-Grand R.	Fair	Very Good	Very Good	Fair	Poor		X
8A	Poor	Fair-Speed R. Fair-Grand R.	Good	Very Good	Very Good	Good	Good	X	
8B	Poor	Fair-Speed R. Fair-Grand R.	Fair	Very Good	Very Good	Good	Good	X	
9A	Very Good	Poor-Speed R. Poor-Grand R.	Very Good	Very Good	Very Good	Good	Very Good	X	
9B	Good	Good-Speed R. Good-Grand R.	Very Good	Good	Poor	Fair	Good	X	
10	Good	Fair-Speed R. Fair-Grand R.	Very Good	Very Good	Good	Fair	Very Good	X	
11	Good	Fair-Speed R. Fair-Grand R.	Very Good	Good	Poor	Poor	Fair		X

* Refer to Table B.2 for plan descriptions.

** Plans considered for further analysis are labelled 'In', those that were not studied further are labelled 'Out'.

B.3.2 The Evaluation Matrix and Plan Screening

The gradings for each plan which resulted from analysis of the basin study team responses are summarized in Table B.18 (Columns 1 to 6). Each plan is described by its objective completion, costs, and social and environmental impacts.

Each column parameter was ranked using the following numerical rankings for a descriptive evaluation.

Descriptive Evaluation	Numerical Ranking
Very Good	4
Good	3
Fair	2
Poor	1

Since some of the parameters may be considered more important than others, they were weighted for the purpose of fuzzy set analyses according to the preferences expressed by the basin study team. The preference weightings as a fraction of 1 for the evaluation parameters were:

Parameter	Weighting by Basin Study Team
1) Objectives	
Flood Damage Reduction	0.70
Adequate Water Quality	0.66
Adequate Water Supply	0.89
2) Costs	0.68
3) Impacts	
Environmental	0.54
Social	0.56

The preference weighting of the evaluation parameters by the study team was similar to that of the public consultation working groups. However, the study team put slightly more emphasis on cost as a means of evaluating the plans.

Fuzzy set analysis was then used to compare one plan with another. This was done by comparing a particular weighted parameter for a given plan with the corresponding weighted parameter of the other plans (Table B.19).

This comparison was then used to grade the individual plans from very good to poor as shown in the evaluation matrix (Table B.18, Column 7). The plans that were ranked very good to good were included for further study, while those ranked fair or poor were removed from further consideration (Table B.18, Columns 8 and 9; Table B.19).

The preliminary screening of the twenty-six water management plans using a multi-criteria method for evaluation eliminated seven plans from further consideration, reducing the number of plans to be studied to nineteen.

This screening process was only one of several screening techniques used by the basin study to evaluate the various water management plans. The entire evaluation process is described in Appendix B.2.

Table B.19

Screening of Water Management Plans Using Fuzzy Set Analysis

Grading	Plan Ranking	
Very Good	1F 1A, 1i 9A 2E, 10 6	Plans accepted for further review
Good	2C, 2B 1G 1C, 1B 1D, 2A 2D, 8A, 9B 4 8B	
Fair	1E 1H, 3 11	Plans eliminated from further review
Poor	7A 7B 5	

Plans are listed in order of their ranking.

C. TECHNIQUES USED IN ECONOMIC ANALYSES

C.1 Discount Rates

Projects have a lifetime, usually extending over several decades. Generally, they yield benefits at least intermittently over that lifetime, and usually they incur some costs during that period. If the costs per year and the benefits per year were constant over the lifetime, to compare a year's benefits to a year's costs would suffice to determine whether the project was worthwhile. Such a situation is depicted by the benefit and cost lines B_1 and C_1 in Figure C.1. However, project costs and benefits are usually very unevenly distributed. Costs are heavy during an initial construction period, then taper off to operating costs alone, and increasing maintenance costs follow. Benefits may be accrued uniformly from the start of a project but usually increase to a maximum over time.

For example, benefits stemming from reduced flood damages occur over the life of a flood control project such as a dam or dyke. However, construction costs occur over a short period of time at the beginning of the project. Because of the very different time-frames of the benefits and the major costs, the two cannot be compared directly. Such situations are depicted as benefit and cost lines B_1 and C_1 in Figure C.1.

The question then is: how do we compare benefit and cost values that are anticipated to occur at different points in time? One scheme might be simply to add up the benefit and cost values over the life of the project. Yet it requires little emphasis in a world filled with interest rates, bond issues, loans, and financial institutions to realize that a dollar in the hand is considered more desirable than a dollar one or ten years hence. People, corporations, and governments appear very willing to pay a premium (i.e. interest) to have money available for use today rather than in the future.

Many people are willing to pay interest for immediate acquisition of consumer durables: homes, cars, televisions, and so on. They frequently exhibit this preference for satisfaction today over satisfaction tomorrow, usually referred to in technical jargon as 'a positive (rate of) time preference.' Corporations are willing to pay interest or share profits to get money today because they have profit opportunities that predictively will return more on their use of funds (resources) than what they will have to pay in interest or dividends. Provincial and local governments borrow to expedite capital expenditures. (This borrowing also makes it possible to spread the cost of common public facilities out over time).

Due to the premium society places on immediate satisfaction of its needs, the time factor emerges as an important element in assessing the value of benefits

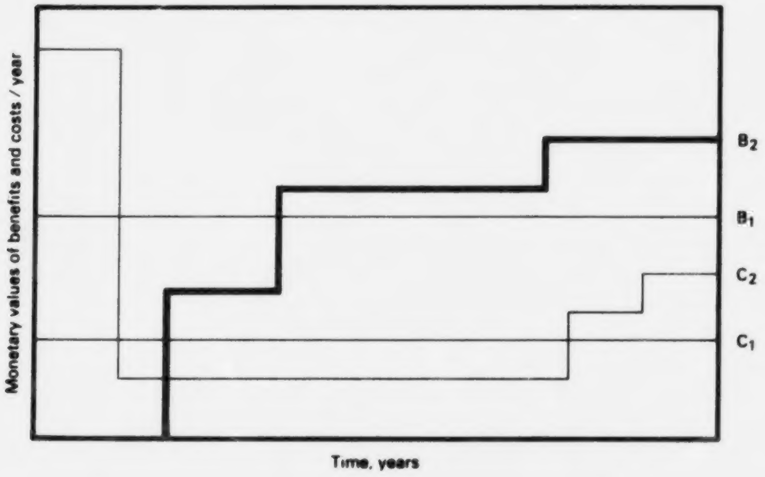


Figure C.1. Project benefit and cost streams over time.

which will occur in the long-term. In fact, all the benefits and costs predicted to occur at different points in time over the life of a project should be weighted differently according to their time of occurrence. Only then can the benefits and costs be considered as comparable units of social value.

Generally, the relative valuation of sums available at different points in time is a matter that society or at least the public sector must decide for itself. To establish a relative scale of values for benefits and costs, i.e. to weight benefits and costs, so that they can be compared realistically, a weighting function called a discount rate can be used. A discount rate is the measurement of the premium one is willing to pay at the present time in order to start enjoying the benefit of a commodity now, rather than later in the future. Conversely, that same premium (i.e. rate) must be subtracted (discounted) from future benefits in order to give them their present day value.

In order to calculate the present value of costs and benefits, the following mathematical equations are used:

If d_1 represents a discount weight for year 1, then we could add the weighted future values to get a present value equivalent:

$$PV = d_0V_0 + d_1V_1 + d_2V_2 + \ldots + d_nV_n$$

where V_n is the value coming due or falling in year n.

How are the weights $d_0, \ldots, d_n$ determined? Granting that they should decrease over time and that d_0 (the weight given to immediate values) should be 1, we usually assume (generally for lack of better foresight) that the weights should decrease into the future in a geometric fashion akin to compound interest. If the rate of decrease is r, then

$$d_{n-1} = (1 + r)d_n$$

$$d_{n-2} = (1 + r)d_{n-1} = (1 + r)^2d_n$$

$$d_1 = (1 + r)d_2 = (1 + r)^{n-1}d_n$$

$$d_0 = (1 + r)d_1 = (1 + r)^nd_n$$

Since we have assumed that $d_0 = 1$, then $d_n = [1/(1 + r)^n]$, and from the above equations we can reason that

$$\begin{aligned} d_{n-1} &= 1/(1 + r)^{n-1} \\ d_{n-2} &= 1/(1 + r)^{n-2} \\ &\vdots \\ d_1 &= 1/(1 + r) \end{aligned}$$

The parameter r is the discount rate.

The selection of a discount rate "r" is critical as it may have a profound influence on plan selection. The present value of future impacts is lower the higher the discount rate. The opposite is also true. High discount rates therefore "favour" projects with little initial investment, while low discount rates "favour" capital intensive projects.

Inflation

Two approaches to discounting are often used. One approach, the one used by the basin study, assumes that future costs and benefits are constant throughout the fifty-year planning period and the discount rate (called the real discount rate) is free of any inflationary premium. An alternative to constant prices is to incorporate inflation into future prices. If this is done, the discount rate (called the nominal discount rate) must include the corresponding inflation component.

For example, with an inflation rate of 10 percent per year, the study's real discount rate of 6 percent is equivalent to a nominal discount rate of 16 percent (10 percent + 6 percent).

Regardless of which approach is selected, the results of the analysis are the same and are based on constant dollar measures of value. The impact of inflating prices in the second approach is fully and exactly offset by the inflationary component of the discount rate.

For the basin study, costs and benefits were assumed to accrue over a fifty-year planning period. At the end of this period, future costs and benefits become insignificant due to the effects of discounting.

To examine the sensitivity of the plans to various discount rates, all water management plan costs and benefits were discounted using rates of 4, 6, 8 and 10 percent. These rates were chosen since it was indicated in a study that a discount rate of 6 percent with a range of 4 to 8 percent was a practical choice (Ref. Tech. Report No. 23). A higher rate of 10 percent was also examined since the Federal Treasury Board recommended it as a suitable rate.

A more detailed explanation of discount rates and their appropriateness for determining plan costs and benefits is presented in Technical Report No. 23.

C.2 An Economic Measure of Water Supply Benefits

This appendix describes a dollar measure of project benefits that has been used to quantify water supply benefits in the Grand River Basin Water Management Study. This measure, called consumer's surplus, was developed by economists using information contained in demand curves for goods and services. Municipal water supply is used here to illustrate the concept.

In Ontario, municipal water supply systems generally charge less than $2.00 for a thousand gallons of water. Water consumption patterns reflect the fact that this price is low; widespread efforts to conserve water are uncommon. Economists argue that the use of water will be reduced if prices increase. They use a demand curve, shown in Figure C.2, to describe this inverse response of consumption to price. Each point on the demand curve indicates how much a consumer would be inclined to consume at the corresponding price. The demand curve therefore reveals how much consumption would change as prices are raised or lowered.

Demand curves also reveal the value attributed to water by consumers. To understand this, consider the point A in Figure C.2. At this point, Qa water is consumed at price Pa. This quantity likely includes drinking, washing, cooking and some outdoor uses. At a zero price, new uses are added that push consumption to Qo. These uses are not, however, warranted at the price Pa; i.e. their value is too low. Looking at the demand curve, this judgement of value is obvious from the fact that the consumer is not willing to pay a price of Pa for consumption beyond Qa. Moving in the other direction, it is equally clear that he would pay more than Pa for most uses between a zero consumption level and Qa. Basic consumption needs are very important. These might amount to Qb in Figure C.2 and would be given a value of at least Pb as shown. The price Pb therefore measures the value of water consumed at the level Qb.

This information about value translates directly into a measure of benefit. At point B on the demand curve, the consumer uses water valued at Pb but on the basis of current pricing practices pays only Pa for the water. He receives a surplus of value measured by the amount "C". Likewise, a similar surplus of value is enjoyed for most of his consumption up to the level, Qa, at which point value equals price and consumption stops. Consumer's surplus is simply the sum of these surplus values. It measures the net benefit a consumer receives when he can purchase water at the price Pa. Mathematically, it is derived as the area under the demand curve up to the point A minus the total expenditure measured as (Pa x Qa).

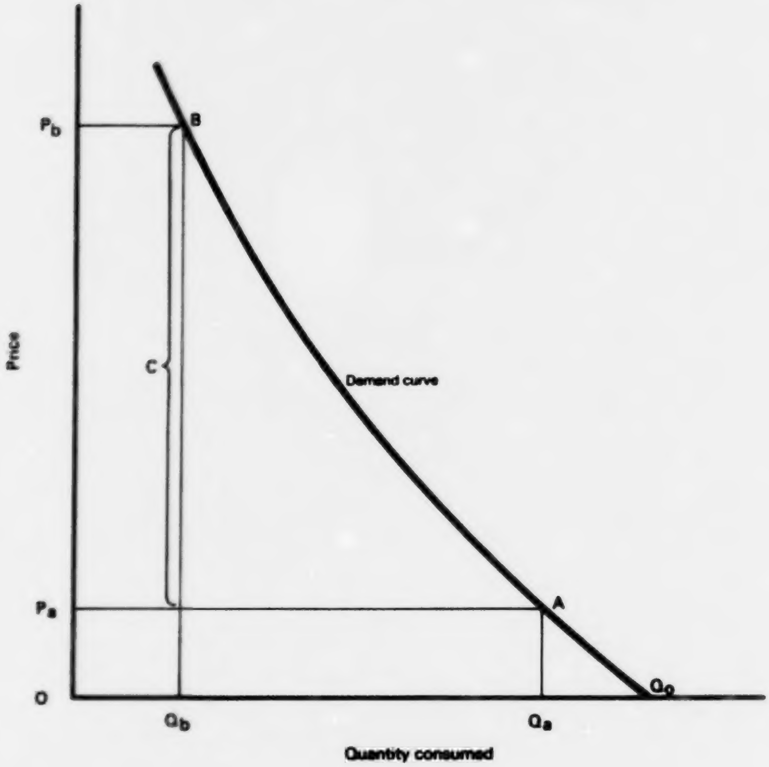


Figure C.2. Demand curve for water.

C.3 Cost Allocation for Multi-Purpose Reservoirs

Certain reservoir projects considered by the Grand River Basin Water Management Study help meet more than one objective while other reservoir and non-reservoir projects have only a single purpose. In the evaluation process it is useful to compare project costs to the performance of projects in meeting the various planning objectives. This comparison must be made for each objective separately since no satisfactory summary measure of performance combining all three objectives is available. This need to separate objectives is problematic because the multi-purpose reservoirs have costs which can be attributed to more than one objective. A comparison for a single objective based on total costs for all projects would be misleading since it would not account for the attainment of the other objectives. The multi-purpose projects would be given an overly pessimistic rating as a result. To overcome this, total costs for multi-purpose projects can be apportioned to various objectives. The comparisons can then be conducted on the basis of allocated costs. Such a procedure, however, is also misleading, since, for the multi-purpose project, the rated performance for one objective cannot actually be achieved for the allocated costs alone. The total project must be built in order to obtain any of the benefit. Therefore, using allocated costs, multi-purpose projects are unduly favoured in a comparison.

In this basin study, the performance-cost comparisons are considered to be a useful means of displaying project data and are not intended to form the basis for overall evaluations of management plans. For this reason, allocated costs seemed more to the point and the associated problems of favouring multi-purpose projects did not seem serious since the eventual project selection is based on a comparison of comprehensive management plans that included groups of projects. At this level, total costs formed the basis for evaluation and selection.

The procedure used here to allocate project costs is called the "separable costs — remaining benefits" method (Ref. A1).

This method distinguishes between separable costs and joint costs. Separable costs are those costs that can be attributed to specific uses. They are determined by subtracting from total project costs the total costs that result when the project is redesigned to exclude a particular use. Defined in this manner, the separable cost is the incremental cost incurred in order to include a use in the project design. A separable cost can be estimated for each objective fulfilled by the project.

Joint costs are defined as total multi-purpose project costs minus the sum of all estimated separable costs. They are the residual costs that cannot be allocated to individual uses on the basis of project design. Joint costs are allocated to each use in proportion to net or "remaining" benefits associated with each use. Remaining benefits are estimated as total benefits related to a use minus the separable costs for that use. Where there is an alternative single-purpose project that can produce equivalent benefits for that use, then the cost of the alternative project must be compared to total benefits for the use. If the single-purpose project costs are less than the value of the total benefits then remaining benefits are calculated as the alternative project costs minus separable costs. The lesser of total benefits and alternative project costs are called justifiable costs.

The total allocated cost for an objective is its separable cost plus the allocated joint cost for that objective. In summary, we have for a project with two uses — flood protection (FP) and flow augmentation (FA):

1. **Total Cost of Project**
2. **Purpose**
   a) **description of uses**
   b) **storage required for single use, FP or FA**
   c) **storage cost is a direct function of the amount of water required in storage to serve a single use, FP or FA, (i.e. the higher the dam, the larger the storage, and the greater the cost)**
3. **Separable cost for FP = (total project cost including FP) — (total project cost without FP)**
4. **Total Joint Cost = (total project cost) – (separable cost for FP and FA)**
5. **Total benefits are obtained from economic analyses in Appendix B and Chapter 10 of the main report. For the Montrose reservoir, Table C.1, the reduction in flood damages is $8.6 million and the reduction in costs for advanced sewage treatment facilities as a result of flow augmentation is $13 million.**
6. **Alternative projects are other projects that could achieve similar results as the proposed project.**
7. **Justifiable costs for FP = minimum of (benefits from FP use, alternative cost to fulfill FP use).**
8. **Remaining benefits for FP = (justifiable cost for FP) – (separable cost for FP).**
9. **Allocated Cost**
   a) **Joint costs allocated to FP = (total joint costs) × [remaining benefit for FP/(remaining benefit for FP + remaining benefit for FA)]**
   b) **Total costs allocated for FP = (separable costs for FP) + (joint costs allocated to FP)**

Tables C.1 and C.2 outline the cost allocation according to the above calculations for the Montrose and Wallenstein reservoirs relative to flood protection and flow augmentation.

In this study, separable costs for multi-purpose reservoirs have been defined strictly on the basis of storage requirements needed to allow for each use. It was assumed therefore that overall project design would not change but the scaling would change for the different uses. This assumption is justified because no uses considered here involve radical design changes such as would be required to accommodate hydro-electric generation for instance.

Cost allocation was required for two reservoirs — Montrose and Wallenstein. The data and calculations used to allocate their total costs are given in Tables C1 and C2. Data problems necessitated some assumptions about benefits and alternative costs in this work. These assumptions are approximate and result in an analysis that is quite crude. The resulting values are generally reasonable but must be used with caution. In particular, this analysis is not considered robust enough to support conclusions about cost-sharing arrangements that could arise once these projects were implemented (even though this type of cost allocation exercise is generally undertaken to determine cost-sharing).

Table C.1 Cost Allocation for Montrose Reservoir
(Present Value of Costs and Benefits in Millions of 1979 Dollars at 6% Discount)

1. Total Cost	$42.4	
2. Purpose:	Use 1	Use 2
a) description	Flood Protection	Flow Augmentation
b) storage — million m^3 required	24.67	54.27
storage — (acre-feet)	(20,000)	(44,000)
c) storage cost	$31.4	$36.6
3. Separable Cost	$ 5.8	$11.0
4. Total Joint Cost	$25.6	
5. Total Benefits	$8.6	$13.0
6. Alternative Project:		
a) description	Salem (single-purpose), Wallenstein and St. Jacobs (single-purpose) Reservoirs	Everton, Wallenstein and St. Jacobs (multi-purpose) Reservoirs
b) cost	$79.9	$74.3
7. Justifiable Cost	$8.6	$13.0
8. Remaining Benefit	$2.8	$2.0
9. Allocated Costs:		
a) Joint Costs	$14.9	$10.7
b) Total Costs	$20.7	$21.7

Table C.2 Cost Allocation for Wallenstein Reservoir*
(Present Value of Costs and Benefits in Millions of 1979 Dollars at 6% Discount)

1. Total Cost	$32.8	
2. Purpose:	Use 1	Use 2
a) description	Flood Protection	Flow Augmentation
b) storage — million m^3 required	17.27	17.27
storage — (acre-feet)	(14,000)	(14,000)
c) storage cost*	$31.4	$31.8
3. Separable Cost	$1.0	$1.4
4. Total Joint Cost	$30.4	
5. Total Benefits	$2.7	assumed $0.0 to $2.7
6. Alternative Project:		
a) description	Salem (single-purpose)	St. Jacobs Reservoir (multi-purpose)
b) cost	$22.0	$24.9
7. Justifiable Cost	$2.7	$0.0 to $2.7
8. Remaining Benefit	$1.7	$0.0 to $1.3
9. Allocated Costs:		
a) Joint Costs**	$30.4 - $17.3	$0.0 - $13.1
b) Total Costs	$31.4 - $18.3	$1.4 - $14.5

* The cost difference arises because of O&M costs.

** A range is given because of uncertainty in estimating benefits from flow augmentation. Further studies would be required to determine flow augmentation benefits.

D. SIMULATION MODELS

D.1 Hydrologic Models

The Grand River Basin Water Management Study used three major models in simulating the effect each water management plan had upon the streamflow regime of the basin. This appendix briefly describes the following three major models:

Flood 2 Model	– used to model high flow events
Reservoir Yield Model	– used to model the effects of existing and proposed reservoir operations on the low flow regime
HEC 5 Model	– used to model the effects of existing and proposed reservoirs upon flood events

Further details of the individual models are described in Technical Report Nos. 36, 37 and 38.

FLOOD 2 Model

Flood 2 was developed by the Conservation Authorities Branch, Ministry of Natural Resources for computing synthetic storm hydrographs for a river system where many sub-watersheds must be considered. The 1975 version of FLOOD 2 was modified by the Grand River Conservation Authority (1980) in order to add flexibility for use in the Grand River Basin Water Management Study. The program develops synthetic hydrographs in accordance with the Soil Conservation Service procedure for subwatersheds in a river system. It combines and then routes these hydrographs through the basin.

For each sub-basin watershed, a synthetic hydrograph is developed. This hydrograph is then combined with adjacent or upstream hydrographs and routed through the basin using one of three available channel routing techniques. Runoff volumes are computed using the Soil Conservation Services curve number method and the synthetic hydrographs are constructed using the SCS triangular unit hydrograph approach (Ref. A2). Available channel routing techniques are:

1) Muskingum
2) Storage-indication
3) Variable storage coefficient.

Flows can also be routed through small reservoirs by using the storage indication method.

The FLOOD 2 model was calibrated for the entire Grand River watershed and verified on the April, 1975 flood event. FLOOD 2 was used to simulate the 5, 10, 25, 50, and 100-year flood events on the Grand river. These simulated flood events were then used to compute average annual damages due to flooding. The regional storm, centred at several locations, was also investigated.

Reservoir Yield Model

The Reservoir Yield program was developed by the U.S. Army Corps of Engineers, Hydrologic Engineering Centre, California, for the testing, sizing and operating policies of conservation reservoirs. The program simulated monthly reservoir operation for a single reservoir operated to meet downstream flow targets.

With reservoir storage areas defined in Figure D.1, reservoir operation is simulated as follows:

If, at any given time, the water level is within the:	Then, the reservoir discharge is determined by:
flood pool	discharge necessary to lower reservoir level to conservation pool, downstream channel capacity not to be exceeded.
conservation pool	required discharge from reservoir or discharge required to meet downstream target flow, whichever is greater.
buffer pool	discharge required to meet downstream flow target, reduced by % storage deficit.
dead storage	discharge equal to or less than inflow.

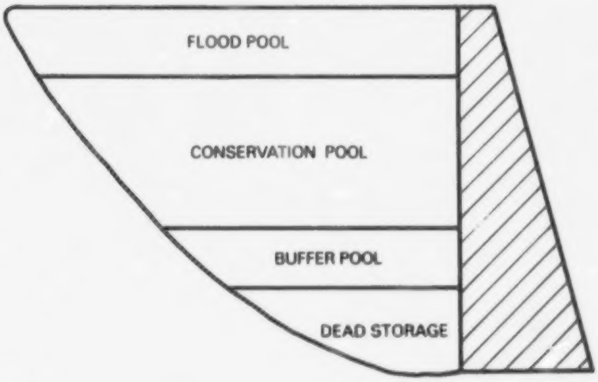


Figure D.1. Reservoir storage areas as defined in reservoir yield and HEC 5 simulation models.

The program was modified by the Grand River Conservation Authority to:

1) simulate operation of a system of reservoirs
2) allow simulation of weekly or daily reservoir operation.

The major difference in the operating logic between the Reservoir Yield program and the HEC-5 program lies in the handling of discharge when the water level is in the buffer pool. The buffer pool is storage required for augmentation later in the year. Reservoir Yield decreases augmentation by a small amount, causing the downstream flows to drop slightly below the target flow. This logic is very realistic. HEC-5 makes discharge equal to minimum required discharge; operation is not determined by the degree of shortage. Results from HEC-5 are not as realistic. This difference in logic is important when testing a reservoir system barely capable of meeting its demands. The Reservoir Yield program was used to:

1) test various operating policies for the existing reservoir system
2) determine the effects of proposed reservoirs on summer low flows.

Reservoir Operation Model HEC-5

The computer program HEC-5 (June, 1979) was developed by the U.S. Army Corps of Engineers at the Hydrologic Engineering Center, California, for evaluation of proposed flood control and conservation systems. The Grand River Basin Water Management Study used the flood control portion of the program to assess the flood damage reduction potential of the existing system plus nine alternative systems (the conservation portion was not used — see Reservoir Yield Model, Figure D.1).

HEC-5 defines a basin's river system in terms of control points, flows and routing co-efficients. The control points include reservoirs and flood damage centres as shown in Figure D.2. Flows can be observed, natural or local and routing co-efficients are used to route reservoir discharges and local flows.

Reservoir operations for flood control use the following basic rules:

1) when reservoir level is in flood pool the program attempts to draw down to top of conservation pool without exceeding channel capacity of downstream control points
2) when reservoir level is at top of flood pool, discharge is set equal to inflow
3) desired flow at downstream control points is released when reservoir level is in conservation pool; required flow at downstream control points is released when reservoir level is in buffer pool.

One typical HEC-5 computer run consisted of a reservoir system operating on each of five natural flood events (FLOOD 2) to produce corresponding regulated flows at downstream control points. At each control point, the regulated peak flow was associated with a damage and frequency. The resultant damage-frequency curve for the 5 events was integrated by the program to produce average annual flood damages for the control point. Damages for all control points within a reservoir system were summarized to produce an average annual flood damage for the system.

The potential flood damage reduction for a proposed reservoir system was found by comparing its average annual flood damages with that of the existing system.

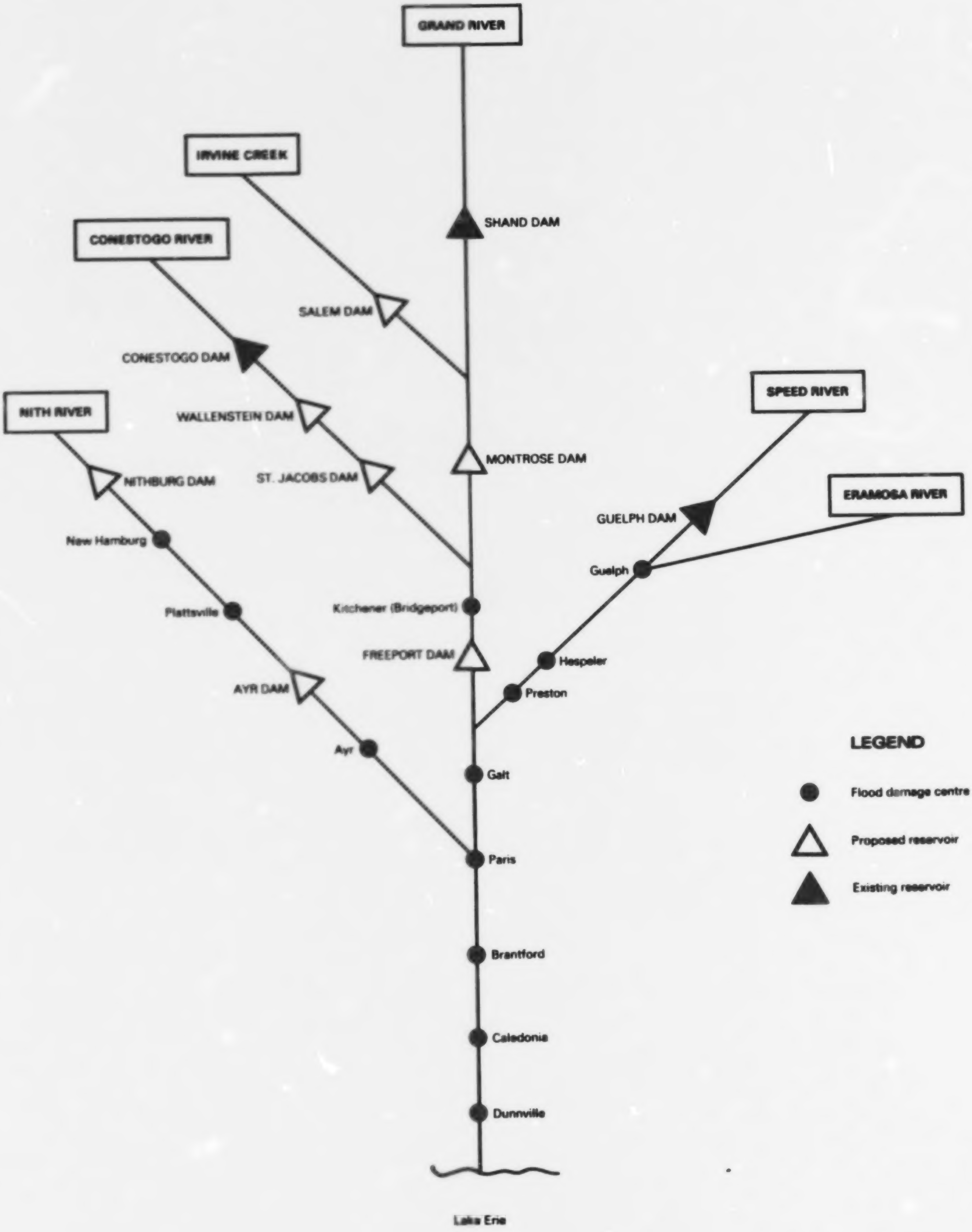

GRAND RIVER
IRVINE CREEK
CONESTOGO RIVER
SHAND DAM
SALEM DAM
CONESTOGO DAM
WALLENSTEIN DAM
NITH RIVER
MONTROSE DAM
SPEED RIVER
NITHBURG DAM
ST. JACOBS DAM
ERAMOSA RIVER
GUELPH DAM
New Hamburg
Guelph
Plattsville
Kitchener (Bridgeport)
FREEPORT DAM
Hespeler
Preston
AYR DAM
Ayr
Galt
Paris
Brantford
Caledonia
Dunnville
Lake Erie
LEGEND
● Flood damage centre
△ Proposed reservoir
▲ Existing reservoir

Figure D.2. Flood damage centres and reservoirs modelled in HEC 5.

D.2 Water Quality Simulation Models

The water quality simulation procedure for the Grand River Basin Water Management Study consisted of a package of three major models, which are described in this appendix. For further details about the models and the many supporting programs the reader should refer to Grand River Technical Report No. 30, "Water Quality Simulation Models and Modelling Strategy for the Grand River Basin."

The three models described herein are: (1) the aquatic plant model, ECOL1; (2) the steady state model, DOMOD7; and (3) the dynamic simulation model, GRSM.

ECOL1

The aquatic plant model, ECOL1, is an independent, continuous simulation model which is capable of simulating the seasonal and daily growth of three aquatic plant types, specifically **Cladophora glomerata, Potamageton pectinatus** and periphyton. In simulating the growth of these aquatic plants, the model accounts for a variety of processes including: the release of oxygen from photosynthesis and the uptake of dissolved oxygen by respiration of the plants; the uptake and release of soluble nitrogen and phosphorus, including luxurious uptake of phosphorus: advective transport of soluble nutrients and dissolved oxygen into and out of each simulated reach; loss of standing biomass through death and washout; and the effects on growth of incident light variations, turbidity, self-shading and temperature. Various physical processes such as aeration-deaeration and changes in river depth, width and velocity associated with changing hydrologic conditions are also simulated.

DOMOD7

The DOMOD7 model is a steady state water quality simulation model which simulates a twenty-four hour period on a two-hour time step. The model accounts for such instream processes as carbonaceous and nitrogenous oxygen demand, reaeration from weirs and dams, and all processes included in ECOL1. A version of ECOL1 was modified and incorporated into DOMOD7 as a subroutine. This provides for estimates of dissolved oxygen and nutrient fluxes which are corrected for the plant biomass within each simulated reach. DOMOD7 predicts instream concentrations of dissolved oxygen, biochemical oxygen demand, nitrogenous oxygen demand, nitrite plus nitrate, suspended solids, and total phosphorus.

DOMOD7 also has the capability to account for the input of up to two point sources, such as sewage treatment plants, or tributaries into each reach. DOMOD7 is useful for examining the effects of point source remedial measures and upstream flow changes upon instream pollutant concentrations.

GRSM

The Grand River Simulation Model, GRSM, is a dynamic (continuous simulation) water quality model which is capable of long-term simulations (up to twenty years) on a two-hour time step. The model incorporates all the features of ECOL1 and DOMOD7, and includes the same processes. The model simulates instream levels of dissolved oxygen, biochemical oxygen demand, nitrogenous oxygen demand, nitrite plus nitrate, unionized ammonia, suspended solids, total phosphorus; and also predicts daily and seasonal biomass growth along with the associated fluxes of soluble nutrients and dissolved oxygen in each simulation reach.

Upstream water quality and non-point source quality are input to GRSM in the form of cumulative probability distributions, derived from historical data collected during routine monitoring and special field surveys. Flow data were generated using various hydrologic models, such as HEC-5, allowing evaluation of hydrologic conditions associated with various reservoirs and operational policies. The use of the STORM model to generate both quality and quantity of urban runoff for input to GRSM allowed for the testing of the effects of changing populations and land use patterns as well as various control options affecting this source.

Continuous water quality monitoring data were collected and extensive field surveys were mounted during 1975, 1976 and 1977 to provide a sufficient data base for calibration and verification of all three models. Each calibration run on the 1976 data was subjected to rigorous statistical and time series analysis and adjustments of model parameters were made until good agreement with observed data was achieved. Further refinement of the model parameters, such as the statistical testing of results of verification runs on 1977 data, was performed until acceptable results for both calibration and verification were achieved.

Modelling Strategy

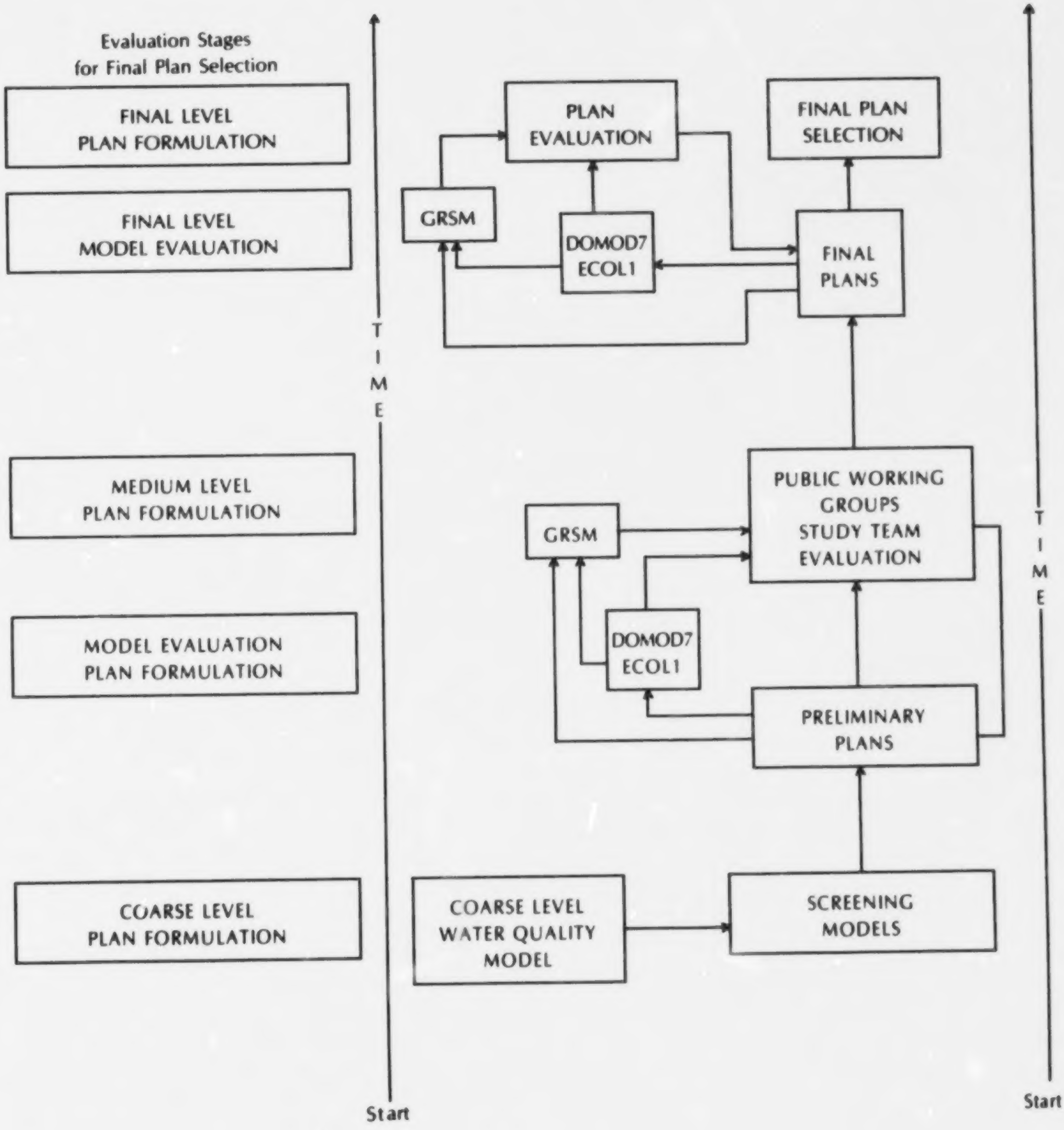
GRSM is expensive in terms of computer costs and requires large and accurate data sets as input for long-term simulation runs. This model provides the best simulation results for long-term statistical evaluation of specific basin management scenarios. In order to reduce computer costs and to provide a quick method of screening many management plans, the three models were used in combination.

DOMOD7 and ECOL1 were used together to provide a relatively quick and inexpensive tool for plan screening. Predicted changes in nutrient concentrations were used as input data for the ECOL1 model. ECOL1 was then run to provide necessary information about impacts on biomass growth which in turn were used in DOMOD7 runs. DOMOD7's role was to assess the improvements in instream dissolved oxygen levels associated with remedial measures for reduction of oxygen-demanding substances at the major sewage treatment plants in the basin.

From the many scenarios tested with DOMOD7 and ECOL1, a few basin management strategies were formulated for evaluation with GRSM. Modifications to these strategies were evaluated using the DOMOD7-ECOL1 package. The most feasible plans based on this screening were then evaluated in detail with GRSM to provide input for the final plan screening process.

Figure D.3 is a simple flow chart illustrating the interrelationships of the working groups, and the roles of the various water quality models in evaluation of management strategies for the Grand river basin.

Figure D.3 Use of Water Quality Models in Evaluation of Management Plans for the Grand River Basin


Evaluation Stages
for Final Plan Selection
FINAL LEVEL
PLAN FORMULATION
FINAL LEVEL
MODEL EVALUATION
MEDIUM LEVEL
PLAN FORMULATION
MODEL EVALUATION
PLAN FORMULATION
COARSE LEVEL
PLAN FORMULATION
TIME
Start
PLAN
EVALUATION
FINAL PLAN
SELECTION
GRSM
DOMOD7
ECOL1
FINAL
PLANS
PUBLIC WORKING
GROUPS
STUDY TEAM
EVALUATION
GRSM
DOMOD7
ECOL1
PRELIMINARY
PLANS
COARSE LEVEL
WATER QUALITY
MODEL
SCREENING
MODELS
TIME
Start

E. WATER QUALITY

E.1 Calculation of the Dissolved Oxygen Water Quality Severity Index

A water quality severity index was used in Chapter 10 to compare the effectiveness of each plan in improving water quality on the central Grand and Speed rivers. The index incorporated time, magnitude (concentration), and spatial extent of non-compliance with the dissolved oxygen objective. The index was developed solely for comparing the various water management plans. It was not intended and is not suitable for more general use.

A zero water quality index indicates that the provincial water quality objective for dissolved oxygen is met 100 percent of the time. Table E.1 illustrates an example of calculating the severity index. For a given reach, the water quality model (GRSM) indicated the percentage of time (Column 2) dissolved oxygen in the stream was within a specified class interval or range (Column 1). The deficit (Column 4) is the amount by which the mean of the class interval lies below 4.0 mg/L of dissolved oxygen, the provincial water quality objective for warm water fish at 20C.

The severity index for a particular reach is then:

$$\text{Deficit (mg/L)} \times \begin{array}{c}\text{\% time}\\ \text{in class}\\ \text{interval}\end{array} \times \text{total length of reach (km)}$$

An example of calculating a water quality index for a river reach, two kilometres in length, is shown in Table E.1.

For n reaches the water quality index is:

$$\sum_{1}^{n} \frac{\text{water quality indices}}{\text{number of reaches}}$$

For 3 months (June, July and August) the water quality index is:

$$\sum_{1}^{3} \sum_{1}^{n} \frac{\text{water quality indices}}{n \times 3}$$

For each main plan the water quality severity indices have been calculated for existing and future conditions and are described in Chapter 10.

While the ultimate goal is to maintain dissolved oxygen at or above 4 mg/L at all times, the practical or "target" water quality index, given natural or uncontrollable upstream influences on the dissolved oxygen regime, was defined for any reach as being not more than 5 percent of the time below 4.0 mg/L and not lower than 3.5 mg/L at any time. These values representing background conditions in the stream were based upon actual measurements of dissolved oxygen made upstream of Waterloo on the Grand river and upstream of the Guelph sewage treatment plant on the Speed river. The desired water quality index was then calculated in a manner as outlined previously (Table E.1). For the same two kilometre reach the desired index is:

Deficit x % of time x length of reach

(4 mg/L - 3.5 mg/L) x 5% x 2 km = desired water quality index

0.5 x 5% x 2 = 5.0

or for n reaches: $\sum_{1}^{n} \frac{\text{desired water quality index}}{n}$

and for 3 months: $\sum_{1}^{3} \sum_{1}^{n} \frac{\text{desired water quality indices}}{n}$

For the basin study, the desired water quality index was 16.7 on the Grand river and 8.7 on the Speed river.

Table E.1 Calculation of the Dissolved Oxygen Water Quality Severity Index

(1) D.O. Concentration (mg/L)	(2) % Time in D.O. Interval For One Month	(3) Mean of D.O. Interval (mg/L)	(4) Deficit 4 mg/L - value from (3)	(5) Length of Reach (km)	(6) Index Values (4)x(2)x(5)
0-2	10	1	3	2	60
2-4	20	3	1	2	40
			Total For Reach - Water Quality Index for month		100

E.2 Water Quality Monitoring

Provincial Water Quality Monitoring Network

Since 1964, the Ministry of the Environment and its predecessor, the Ontario Water Resources Commission, working in co-operation with the Grand River Conservation Authority, has maintained a routine surface water quality monitoring program throughout the Grand river basin. Samples are collected approximately monthly at 40 locations on the main stem and tributary streams. Analysis includes dissolved oxygen and temperature, bacteriological organisms, 5-day biochemical oxygen demand, nitrogen and phosphorus compounds, solids and, at some locations, other physical parameters, salts and metals. Data from this program have been used extensively in the basin study for modelling and general water quality assessments. Complete records of this surveillance program are published annually by the Ministry of the Environment in "Water Quality Data — Ontario Lakes and Streams."

Continuous Dissolved Oxygen Monitoring

Since 1975, the Ministry of the Environment, working in co-operation with the Grand River Conservation Authority, has maintained a network of automated stations which measure and record, continuously, dissolved oxygen and temperature. Stations are located at the following sites:

Grand river at Bridgeport — upstream of the major population centres
Grand river at Woolner's Flats — downstream of the Waterloo sewage treatment plant
Grand river at Blair — downstream of the Kitchener sewage treatment plant
Speed river at Guelph — upstream of the Guelph sewage treatment plant
Speed river at Glen Christie — downstream of the Guelph sewage treatment plant
Speed river at Preston — near confluence with the Grand river
Grand river at Glen Morris — downstream of the megalopolis area

In 1979, automatic stations were added on the Grand river at Brantford. One station was located near the city's water works intake. The other was sited downstream from the sewage treatment plant outfall.

Data from all stations were used for the development and verification of water quality models and for general water quality assessments. Detailed information about these automated stations and summarized data results for the period 1975-1979 are provided in Technical Reports 11 and 11a.

Automated dissolved oxygen/temperature monitoring stations are being maintained jointly by the Ministry of the Environment and the Grand River Conservation Authority at Bridgeport, Woolner's Flats, Blair, Guelph, Glen Christie and Glen Morris so that the effects of remedial measures to improve water quality can be adequately measured.

Proposed Organic Chemical Monitoring Program

During the basin study, samples for trace organic chemical analyses were collected from the main stem of the Grand river, the Speed river, Canagagigue creek and the Elmira sewage treatment plant. A variety of organic compounds were measured at very low concentrations. While there have been very few objectives or guidelines set for these organic compounds, a review of literature indicates that the concentrations measured to date in the river pose no threat to aquatic life or use of the river for water supply.

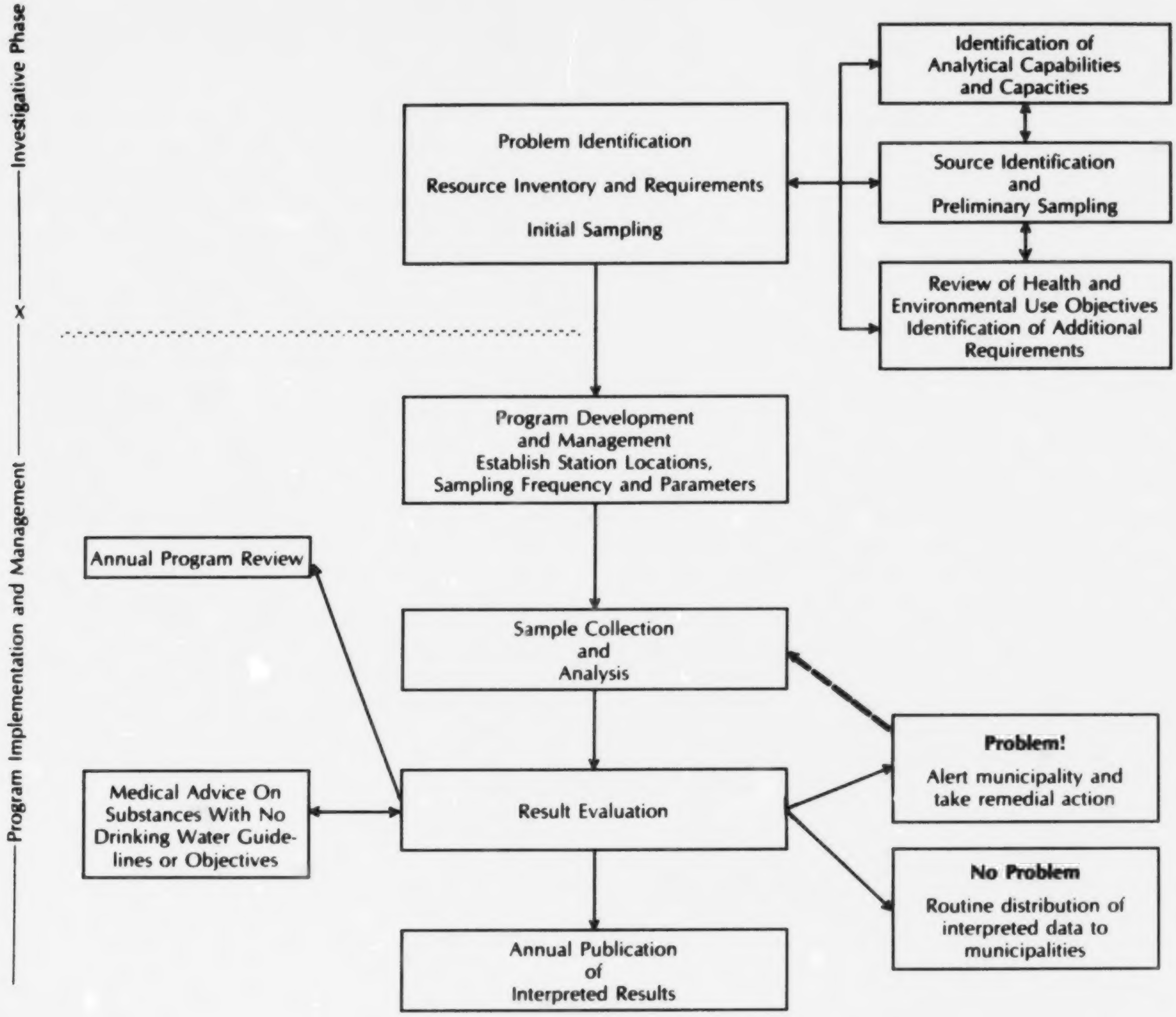
It must be pointed out, however, that the trace organic substance analyses carried out during the basin study were limited in scope. With the existing and growing use of the river for municipal drinking water supply, a more comprehensive program is warranted. To this end, a tentative framework for a trace organic contaminant monitoring program has been prepared and is presented in Figure E.1. The proposed program has two parts: an initial problem identification/resource requirement investigative phase followed by the implementation and management of a routine monitoring program.

The lead agency in the overall program would be the Ministry of the Environment. This agency would, essentially, be responsible for carrying out the investigative phase of the study, organizing the program management team, collecting and analysing samples and reporting results. Medical authorities of the Provincial Government would be asked to provide advice on any required, new drinking water objectives or consumption guidelines and comment upon analytical results as required. Municipalities using the river as a source of water supply could participate in the planning of the program and would receive the interpreted results of analysis routinely. The interpreted results of the program could be published annually.

The precise location of sampling stations can be set only after the investigative phase; however, such stations should include major municipal and industrial point sources, urban drainage sites, the river at municipal water supply extraction points, treated water from these municipalities and control samples from headwater areas of the basin unaffected by municipal or industrial inputs. Lists of substances for routine analysis should be set only after the initial sampling and problem identification activities of the investigative phase are complete.

The entire project should be managed by a team composed of representatives from the Ministry of the Environment, the major municipalities, provincial health authorities, and the basin co-ordinating committee.

Figure E.1 Structure of A Proposed Trace Organic Pollutant Monitoring Program


Investigative Phase
Program Implementation and Management
Problem Identification
Resource Inventory and Requirements
Initial Sampling
Identification of Analytical Capabilities and Capacities
Source Identification and Preliminary Sampling
Review of Health and Environmental Use Objectives Identification of Additional Requirements
Program Development and Management Establish Station Locations, Sampling Frequency and Parameters
Annual Program Review
Sample Collection and Analysis
Problem! Alert municipality and take remedial action
Medical Advice On Substances With No Drinking Water Guidelines or Objectives
Result Evaluation
No Problem Routine distribution of interpreted data to municipalities
Annual Publication of Interpreted Results

E.3 Sewage Treatment Plants

This appendix briefly describes the sewage treatment facilities used to treat the municipal, private and industrial wastes of the Grand river basin.

Municipal and Private Sewage Treatment Plants

All of the municipal treatment facilities in the Grand river basin are listed in Table E.2, with private facilities listed in Table E.3. Also included in these tables are the type of treatment, the capacity, and the general effluent quality of each plant. The locations of municipal sewage treatment plants are shown on Figure 4.5 in Chapter 4.

Industrial Discharges

The vast majority of industries or commercial operations in the Grand river basin with waste discharges are connected to a municipal sewage system and their wastes are adequately treated and discharged along with the municipality's sanitary wastes. There are a number of industries discharging treated wastewater directly to the river. These industries are listed in Table E.4 and are described briefly in the following paragraphs.

Silknit Limited (formerly Dominion Woolens) — Cambridge(Hespeler)

This textile plant located in Cambridge(Hespeler) treats its wastes in an aerated lagoon which discharges continuously to the Speed river, upstream from the Hespeler sewage treatment plant, at a rate of 2400 m^3/d (0.528 mgd). Effluent quality is marginally above the Ministry of the Environment's criteria and remedial action is not justified at this time. However, an increase in the size of the aeration basin is planned which will result in lower organic loads and less dyes being released to the river. The sanitary wastes from the plant are directed to the municipal sewage treatment plant.

J. M. Schneider — Ayr

Wastes from this meat processing plant, located in Ayr, are treated in a conventional activated sludge type plant before being discharged to the Nith river. Organic and phosphorus levels are unacceptably high. Plant flows are 300 m^3/d (0.066 mgd). The problem is under consideration by the Ministry of the Environment. Sanitary wastes are treated in the municipal sewage treatment plant.

Solar Ware — Cambridge(Hespeler)

Metals are cleaned, etched with a nickel solution, and porcelainized in this plant located in Cambridge(Hespeler). Wastes from these processes are neutralized and subjected to floculation and precipitation for metals removal. Although nickel levels were high in 1979 (1.7 mg/L), adjustments have been made to the treatment system with acceptable levels resulting. Flows in 1979 averaged 180 m^3/d (0.04 mgd). Sanitary wastes are directed to the municipal system.

Stanley Works — New Hamburg

This electroplating plant, located in New Hamburg, treats its wastes by various methods including cyanide destruction, chromium conversion, neutralization, floculation and precipitation. Approximately 270 m^3/d (0.059 mgd) of treated wastes are discharged to the Nith river. Although zinc levels were high in 1979, they have been controlled and the discharge is acceptable to the Ministry of the Environment.

Tend-R-Fresh — Petersburg

This poultry processing and rendering plant located in Petersburg, discharges 2700 m^3/d (0.594 mgd) of treated wastes to the head waters of Alder creek. Treatment includes pretreatment for large solids removal (includng feathers) followed by biological treatment with a polishing lagoon being utilized if necessary. Although the aqueous discharges ae generally acceptable to the Ministry of the Environment, the comany has been asked to provide phosphorus removal to 1 mg/L to reduce aquatic growths in Alder creek. Sanitary wastes are treated in the industrial treatment plant.

The company has had a history of odour problems. Local residents have objected to a recent request to increase rendering operations by accepting outside wastes, as odour problems may extend into nightime periods. Sanitary wastes are treated in the industrial treatment plant.

Industries Discharging to Municipal Sewage Systems

There are a great many industries in the Grand river basin which discharge processed wastes directly to the sanitary sewers. In the Kitchener-Waterloo area alone about 300 industries dispose of their wastes in this manner. In most cases no problems result. However, problems have been encountered with the industries discussed below.

St. Jacobs

The St. Jacobs Canning Company discharges high BOD wastes to the sanitary sewer in the fall which interferes with normal operation of the sewage treatment plant. Methods to minimize sewage treatment plant disruption are under investigation.

Fergus

Canada Wire and Cable and Noranda Metals discharge wastes which are high in heavy metals to the town's sanitary sewer. Although operation of the sewage treatment plant is not affected adversely, sewage sludge is above the Ministry of the Environment's guidelines as a result of these inputs.

Elmira

Uniroyal Chemicals Ltd. provide pretreatment of their wastes before discharging to the sanitary sewer. Pretreatment includes aeration and pH and temperature stabilization, followed by carbon filtration. Because of the nature of the Uniroyal wastes, solid setting is inhibited in the sewage treatment plant resulting in a high level of suspended solids in the effluent. As part of the expansion of the Elmira sewage treatment plant, flow proportioning between Uniroyal and the town's wastes will be provided and thus result in less shock loads to the sewage treatment plant. As well, the company is installing a "wet-ox" system to reduce the toxicity of their effluent and treat some waste streams currently being disposed of off-site. Wastes from Borg Textiles are also suspected of placing shock loads on the sewage treatment plant at times.

Paris

Approximately one-half of the hydraulic loading to the sewage treatment plant is provided by Penmans Limited Textile plant. Colours and a high organic load from the dyes used at Penmans interfered with normal operation of the sewage treatment plant and resulted in a poor quality effluent on many occasions. The company is in the process of removing its dying operations from this plant, thereby eliminating this industrial discharge to the sewage treatment plant.

Table E.2 Municipal Sewage Treatment Plants In The Grand River Basin

Municipality	Type of Treatment	Sewage Flows - 1979		Mean 1979 Effluent Quality (mg/L)			Receiving Watercourse	Comments
		Plant Capacity	1979					
		x 10^{3}m^3/d lagoon size in hectares	Average Daily Flow x 10^{3}m^3/d	BOD$_5$	Suspended Solids	Total Kjeldahl Nitrogen		
Arthur	Seasonal Discharge Lagoons	11.6 ha	---	15.0	25.0	15.0	Conestogo River	
Ayr	Extended Aeration	1.05	---	5(e)	15(e)	8.0(e)	Nith River	Completed January, 1980.
Baden	Extended Aeration	0.92	0.5	3.2	7.6	4.4	Baden Creek	
Brantford	Conv. Activated Sludge	57.0	40.9	7.3	13.0	8.9	Grand River	Expansion to 84 x 10^{3}m^3/d virtually completed.
Caledonia	Conv. Activated Sludge	2.3	1.9	8.0	20.0	8.0	Grand River	
Cayuga	Extended Aeration	0.9	---	2.0	8.0	1.6	Grand River	
Dundalk	Seasonal Discharge Lagoons	6.5 ha	---	10.0	18.0	5.0	Grand River	Expansion planned.
Dunnville	Conv. Activated Sludge	7.7	4.4	8.0	12.0	3.8	Grand River	
Elmira	Conv. Activated Sludge	3.1	3.3	17.0	40.0	32.0	Grand River	Expansion planned to 4.6 x 10^{3}m^3/d with filters and nitrification.
Elora	Extended Aeration	0.38	0.92	14.0	40.0	24.0	Grand River	Recently expanded to 3 x 10^{3}m^3/d (1980).
Fergus	Conv. Activated Sludge	5.0	3.0	11.0	14.0	9.0	Grand River	
Galt	Conv. Activated Sludge	38.6	29.3	8.2	9.4	9.9	Grand River	
Grand Valley	Extended Aeration	0.6	0.32	6.0	12.0	12.0	Grand River	
Guelph	Conv. Activated Sludge	45.5	41.4	20.0	22.0	19.0	Speed River	Expanded in 1980 to 55 x 10^{3}m^3/d with nitrifica- and filters.
Hespeler	High Rate Activated Sludge	9.3	5.0	35.0	46.0	17.0	Speed River	
Kitchener	Conv. Activated Sludge	123.0	61.2	13.0	8.0	4.0	Grand River	
New Hamburg	Seasonal Discharge Lagoons	11.1 ha	---	7.0	15.0	12.0	Nith River	Expansion under construction. Discharge will be proportional to streamflow.
Paris	Extended Aeration	2.3	1.9	33.0	40.0	22.0	Grand River	Plant presently being expanded to 6.9 x 10^3/m^3/d.
Preston	Conv. Activated Sludge	19.1	7.9	32.0	53.0	8.0	Grand River	
St. George	Extended Aeration	1.1	---	7.5(e)	7.5(e)	8.0(e)	Fairchild Creek	Under construction — effluent storage, if necessary.
St. Jacobs	Extended Aeration	0.95	1.0 - 0.78*	5.0	16.0	2.5	Conestogo River	Effluent affected by in-industry.
Waterloo	Conv. Activated Sludge	45.5	30.7	9.0	12.0	9.0	Grand River	
Wellesley	Extended Aeration	0.55	0.39	4.0	13.0	1.9	Nith River	

* High flows recorded in 1979 may be due to faulty meter and/or infiltration.

Table E.3 Private Sewage Treatment Plants In The Grand River Basin

Facility	Type of Treatment	Sewage Flows		Mean 1979 Effluent Quality (mg/L)			Receiving Watercourse
		Plant Capacity	1979				
		$10^3 m^3/d$ or lagoon size in hectares	Average Daily Flow x $10^3 m^3/d$	BOD$_5$	Suspended Solids	Total Kjeldahl Nitrogen	
Breslau Hotel	Seasonal Discharge Lagoons	0.81 ha	---	30.0	23.0	0.4	Hopewell Creek
Burtch Correctional Centre	Conventional Activated Sludge	0.2	0.09	9.5	24.0	13.0	Mt. Pleasant Creek
Cainsville Industrial Park	Seasonal Discharge Lagoon	2.4 ha	---	8.0	10.0	---	Fairchild Creek
Ontario Hydro	Seasonal Discharge Lagoons	0.17 ha	---	5.5	11.0	4.6	Big Creek
Oshweken Reserve	Seasonal Discharge Lagoons	1.3 ha	---	15.0	9.0	4.0	McKenzie Creek

Table E.4 Industrial Waste Treatment Plants In The Grand River Basin

Industry	Location	Type of Treatment	1979 Flows x $10^3 m^3/d$	Receiving Watercourse	Major Effluent Constituents
Silknit Ltd. (formerly Dominion Woolens	Cambridge (Hespeler)	Aerated lagoons with continuous discharge	2.4	Speed River	BOD_5 - 34. mg/L, Phenols 68 mg/L, S.S. 35 mg/L, Total P - 0.1 mg/L, Dyes, Detergents
Electric Reduction (Erco) Industries Ltd.	Port Maitland	Recycling	8.5	Grand River	Total P - 5 mg/L, S.S. - 16.3 mg/L
International Minerals and Chemical Corp. (Canada) Ltd. (I.M.C.)	Port Maitland	Recycling and/or lime neutralization	29.4	Grand River	Total P - 17.2 mg/L, Fluorides - 16.3 mg/L, S.S. - 19.4 mg/L
J.M. Schneider Ltd.	Ayr	Biological treatment	0.30	Nith River	BOD_5 - 44 mg/L, S.S. - 69 mg/L, Total P - 18 mg/L, NO - 15.2 mg/L
Solar Ware	Cambridge (Hespeler)	Primary (metal removal)	0.18	Speed River	Ni - 1.7 mg/L, S.S. - 50.3 mg/L
Stanley Works	New Hamburg	Metals removal	0.27	Nith River	Zn - 2.9 mg/L, Cr - 0.3 mg/L, Ni - 0.2 mg/L, Cu - 0.5 mg/L
Tend-R-Fresh	Petersburg	Biological treatment and polishing lagoon	2.7	Alder Creek	BOD_5 - 20 mg/L, S.S. - 36 mg/L, Total P - 3.3 mg/L

KEY

BOD_5 — 5-Day Biochemical Oxygen Demand
S.S. — Suspended Solids
Total P — Total Phosphorus
NO_3 — Nitrate Nitrogen

Ni — Nickel
Zn — Zinc
Cr — Chrome
Cu — Copper

F. WATER QUANTITY

F.1 Average Annual Flood Damages

This appendix briefly describes how the average annual flood damages are calculated for a particular site.

First, an elevation-discharge curve, which shows the relationship between discharge and river water levels is derived for the area subject to flooding (Fig. F.1.a).

Flood damages are then calculated with the use of unit flood damage curves or tables for various types of residential, commercial or industrial structures. These tables represent the total structural and content damage for various depths of submergence.

For each flood elevation in a flood centre, the individual residential, commercial and industrial damages are accumulated and plotted to form an elevation-damage curve as shown on Figure F.1.b.

For each area subject to flooding, a flood frequency curve is developed (Fig. F.1.c). This curve is based upon a statistical analysis of the maximum river discharges.

A damage frequency curve is developed from Figure F.1.a, the elevation-discharge curve; Figure F.1.b, the elevation-damage curve; and Figure F.1.c, the flood-frequency curve.

A damage-frequency curve is shown in Figure F.1.d and in Figure 6.1 in Chapter 6. The shaded area under the curve represents the average annual flood damages.

The average annual benefits as a result of the construction of a dyking system are shown in Figure F.1.e. If it is assumed that the dykes are designed for a flow of 2 m^3/s corresponding to a frequency of exceedance of 2 percent, then benefits are only obtained for flows less than 2 m^3/s.

If a reservoir is designed to offer the same protection as the dyking system in the previous example, the average annual flood damages will generally be lower than those sustained by the dyking system (Fig. F.1.f). This is because the reservoir, with its ability to store flood volumes will often continue to reduce flood flows even when the design flow is exceeded.

In contrast, the dyking system offers protection up to the design flow or elevation. When this elevation is exceeded, the dyking system is assumed to fail and the damage is as large as if there had been no dyking system.

Fig. a. Elevation discharge curve.

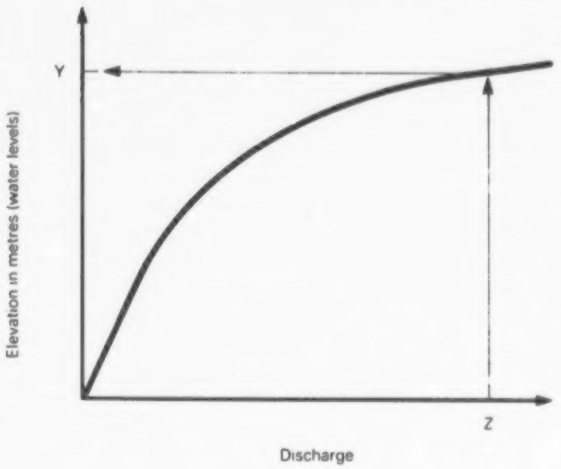


Fig. b. Elevation damage curve of area subject to flooding

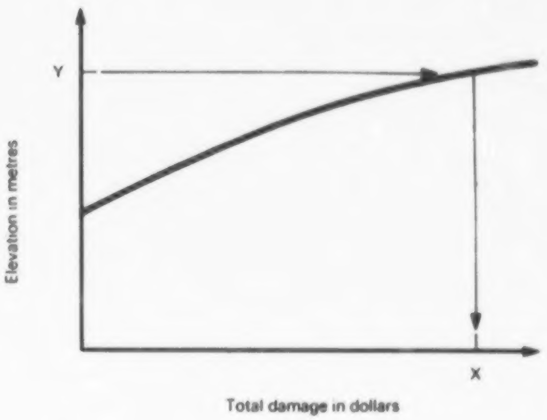


Fig. c. Flood frequency curve of maximum annual flood flows.

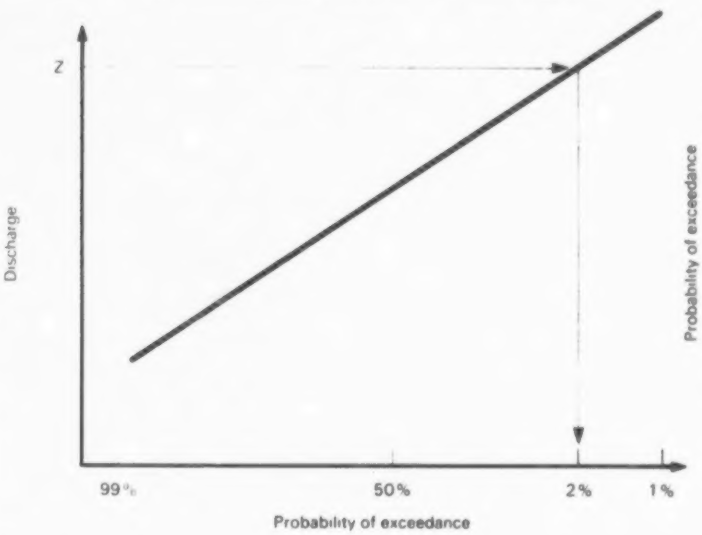


Fig. d. Damage frequency curve of area subject to flooding.

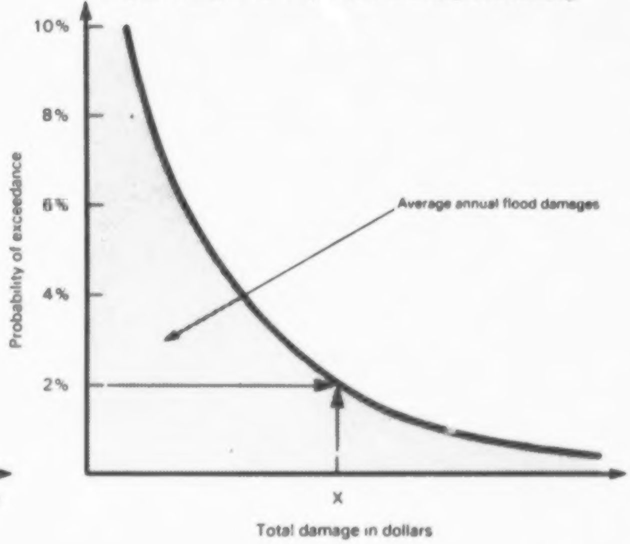


Fig. e. Average annual benefits as a result of building a dyke.

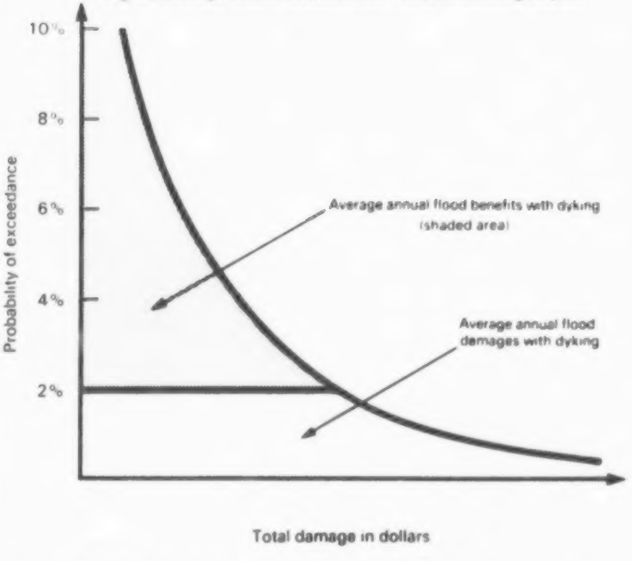


Fig. f. Average annual benefits as a result of building a reservoir.

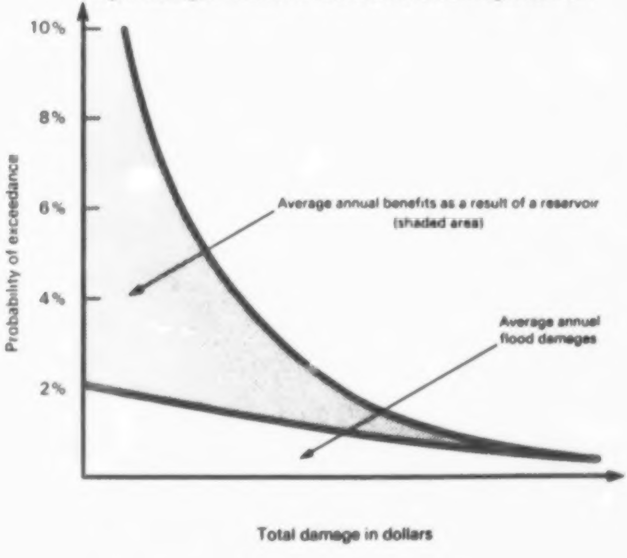


Figure F.1. Average annual flood damages

F.2 Variation of Average Annual Flood Damages With Floodplain Development

The basin study has assumed that the floodplain regulations, as presently administered and enforced, would control future floodplain development. Therefore, existing average annual flood damages are not expected to increase significantly during the 50-year planning period due to floodplain development.

This assumption was based on a review of past floodplain development (Table F.1). For example, the total number of structures in Cambridge(Galt) and Brantford has increased only 5 percent between 1954 and 1976. Since over 85 percent of the average annual flood damages occur in these two cities, the total average annual flood damages should not change materially in the future due to floodplain development.

Table F.1 Floodplain Development for Selected Communities within the Grand River Basin (1954-1976)

Community	Number of Structures Within the Floodplain*	New Structures Erected in the Floodplain**	
		1954-1966	1966-1976
Cambridge(Galt)	746	3 (0.4%)	13 (2%)
Brantford	2694	112 (4%)	48 (2%)
New Hamburg	115	6 (5%)	7 (6%)
Bridgeport	130	19 (15%)	32 (25%)

* Floodplain for this review is defined as the land within the Regional Storm Floodline

** Net result = new structures — structures removed

( ) percentage increase in structures within the floodplain

Source: Ref. A3.

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E. Thompson, Caledonia
J. Vloet, Dunnville

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Grand River Basin

Water Management Study

SUMMARY
AND
RECOMMENDATIONS

Ontario

Grand River
Implementation
Committee
1982

THE GRAND RIVER

Grand River Basin

Water Management Study

SUMMARY
AND
RECOMMENDATIONS

Ontario

Grand River
Implementation
Committee
1982

PREFACE

This report summarizes the water resource problems encountered in the Grand River basin and presents a set of recommendations to guide basin water management.

A more detailed discussion of the study finds and conclusions is available in a full-length report entitled **Grand River Basin Water Management Study.** Technical reports are also available which detail results of individual studies carried out by the study team.

The recommendations in this report were prepared by the Grand River Implementation Committee, made up of members from the following five participating ministries and agencies:

- Ontario Ministry of Agriculture and Food
- Ontario Ministry of the Environment
- Ontario Ministry of Municipal Affairs and Housing
- Ontario Ministry of Natural Resources
- Grand River Conservation Authority

The Committee was aided in making its recommendations by extensive municipal and public consultation programs. Basin municipalities were represented on technical sub-committees and they provided information and advice throughout the study. Public input was provided by four consultation working groups made up of citizens from different areas of the basin.

Additional copies of this "Summary and Recommendations" may be obtained from:

a) in person from the Ontario Government Bookstore, 880 Bay Street, Toronto, Ontario.

b) by mail from the Ontario Government Publications Centre, 5th Floor, 880 Bay Street, Toronto, M5S 1Z8.

c) Grand River Conservation Authority
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Figure

— • Recommended Plan 4

Summary

The main investigative period of the Grand River Basin Water Management Study extended from 1977 to 1981. Its purpose was to define the water management problems confronting the Grand river basin, and to develop a viable set of alternative water management plans. These plans are designed to meet the following water management objectives:

1) reduce flood damages
2) provide adequate water supply
3) maintain adequate water quality.

This study provides a comprehensive framework to aid elected representatives, officials and citizens in resolving water management problems. The framework is flexible enough to accommodate changing water management priorities and needs. It provides a means by which new projects and other plans can be evaluated.

Large scale water management problems are largely confined to the urban and industrial middle portion of the basin. Here, the Cities of Cambridge and Brantford account for over 85 percent of the $980,000 average annual flood damages experienced within the basin. In the Kitchener-Waterloo-Cambridge area, the existing ground water supply for industrial and domestic consumption will have to be supplemented in the next five years by additional surface and ground water supplies. Low oxygen levels occur during the critical summer period in the central Grand river between Kitchener and Glen Morris and in the Speed river downstream from Guelph. This is caused by organic waste discharges and nutrient inputs from six municipal sewage treatment plants and by upstream rural non-point sources. While water management problems are often the most apparent in the middle portion of the basin, flooding, water shortages and water quality impairment are encountered throughout the basin in rural as well as urban areas. Pollution control measures recommended in this report to maintain or improve the water quality within the river basin will also benefit Lake Erie, particularly measures to reduce the input of nutrients.

The basin study examined twenty-six different water management plans and assessed their relative economic, social and environmental costs and benefits associated with meeting the water management objectives. An evaluation process narrowed these alternatives down to the following main plans:

1. plan A1 utilizes dyking and channelization to minimize flood damages, advanced sewage treatment to improve water quality, and induced infiltration wells and artificial recharge of aquifers using river water to augment ground water supplies

2. plan A4 is the same as plan A1, but, in addition, preserves the option of using the Montrose reservoir site for possible future water management purposes. Protection of the site can be achieved by acquiring the land as it becomes available and by various planning controls

3. plan B2 proceeds immediately with construction of the Montrose multi-purpose dam and reservoir. Flood damage reduction is provided by the reservoir as well as by dyking and channelization. Water quality is improved by advanced sewage treatment and increased summer flow from the reservoir. Requirements for advanced sewage treatment when compared with plan A are reduced or delayed. Infiltration wells and artificial recharge are used to augment ground water supplies as in plan A1

4. plan C1 is the same as plan A1 with respect to water quality and water supply measures. It provides flood protection through the construction of a single-purpose or dry reservoir on the Conestogo river at St. Jacobs

5. plan D incorporates the flood protection and water quality measures of plan A1 and provides water supply by the construction of a Lake Erie pipeline.

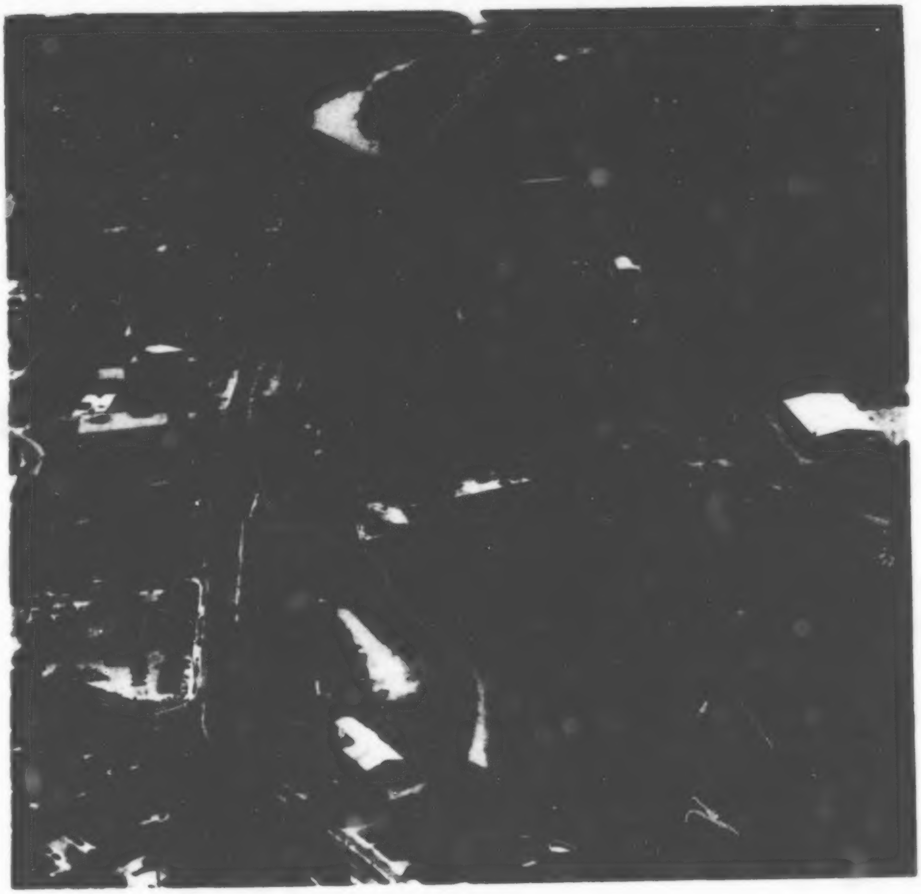
The advantages and disadvantages of these plans are compared in a Table on page 13.

In the initial review of these plans, the basin study assigned lower rankings to plans C1 and D. Plan C1, the St. Jacobs single-purpose reservoir option, will not give adequate flood protection and plan D, the Lake Erie pipeline option, was deemed to be too expensive.

A detailed evaluation of plans A1, A4 and B2 was then carried out. Three of the four public consultation working groups, made up of citizens from different geographical areas of the basin, preferred plan A1 with minimum environmental and social impacts. The fourth group representing the lower portion of the basin, preferred plan B2. The water managers who are charged with the day-to-day responsibility of operating major flood control, water supply and sewage treatment services preferred plan B2 because, in their view, it offered a more reliable and secure water management system.

The overall results of the evaluation incorporating the preferences of all those who participated showed that plans A1, A4 and B2 were ranked very closely.

After a detailed review of the various inputs, the Grand River Implementation Committee, the basin study's co-ordinating committee, identified plan A4 as the preferred plan to meet the water management needs of the basin.



The

Urban

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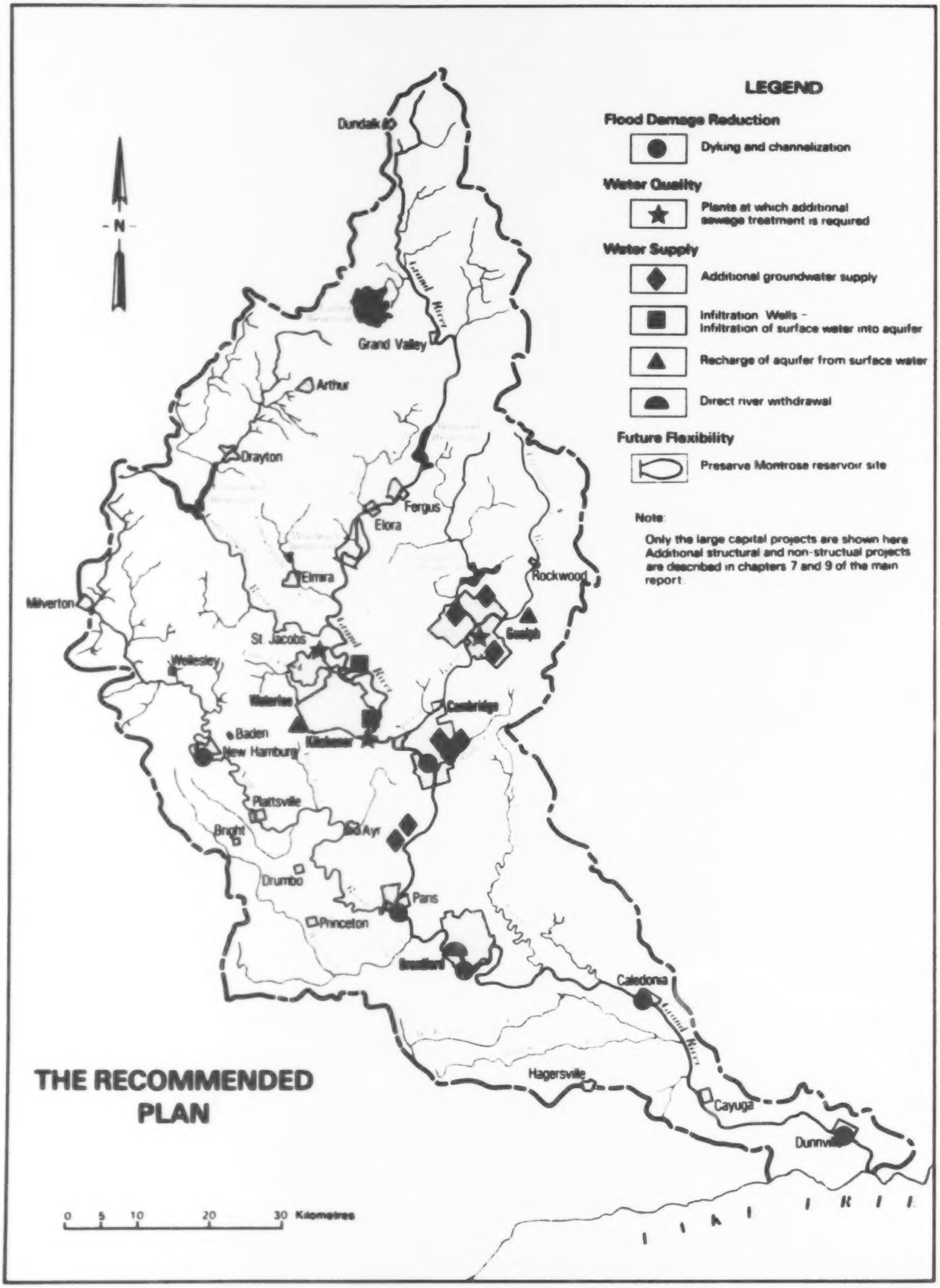

LEGEND
Flood Damage Reduction
● Dyking and channelization
Water Quality
★ Plants at which additional sewage treatment is required
Water Supply
◆ Additional groundwater supply
■ Infiltration Wells - Infiltration of surface water into aquifer
▲ Recharge of aquifer from surface water
◓ Direct river withdrawal
Future Flexibility
Preserve Montrose reservoir site
N
Dundalk
Grand Valley
Grand River
Arthur
Drayton
Fergus
Elora
Elmira
Milverton
Rockwood
Guelph
St. Jacobs
Wellesley
Waterloo
Kitchener
Cambridge
Baden
New Hamburg
Plattsville
Bright
Ayr
Drumbo
Paris
Princeton
Brantford
Caledonia
Hagersville
Cayuga
Dunnville
LAKE ERIE
0 5 10 20 30 Kilometres

Note:

Only the large capital projects are shown here. Additional structural and non-structual projects are described in chapters 7 and 9 of the main report.

THE RECOMMENDED PLAN

Recommendations

A. The Recommended Plan

1. It is recommended that plan A4 and the measures described in the following recommendations be implemented.

The basin study concluded that plan A4 is cost-effective in meeting the water management objectives. It was preferred over plan B2 (the Montrose dam option) for the following reasons:

a) it is approximately $25 million cheaper than plan B2
b) its environmental and social impacts are moderate. The public participation program indicated that there would be opposition to the selection of plan B2
c) it maintains future flexibility by preserving the option of constructing the Montrose dam if future water quality or water supply problems require it
d) it provides a high degree of flood protection for urban areas
e) it provides for population growth by fully meeting projected municipal water demands and improving water quality in the central Grand river
f) it improves water quality in the central Grand river, although the dissolved oxygen levels will not fully meet the provincial water quality objectives. While plan A4 does not provide as high a water quality as plan B2, it provides a reasonable level of protection for most water uses at a substantially lower cost.

Plan A4 is the same as plan A1 except that land acquisition raises total plan costs by $4 million and increases the social impacts. It was preferred over plan A1 primarily because it maintains future flexibility by preserving the Montrose reservoir lands.

In the opinion of the Grand River Implementation Committee, plan A4 represents the best overall solution to basin water management problems. The recommendation of this plan does not necessarily preclude selection of all or part of another. This report defines the water management problems confronting the Grand river basin and establishes a framework within which water management projects and measures can be implemented. The framework is flexible enough to accommodate future water management priorities and needs.

B. Recommendations for Reduction of Flood Damages

The basin study investigated both structural and non-structural methods of reducing flood damages. Structural methods include dyking, channelization, reservoirs and flood proofing. Non- structural methods include regulations, zoning and land use practices.

1. It is recommended that channelization and dyking be constructed to reduce flood damages at the major flood damage centres.

Average annual flood damages at Cambridge, Brantford, Paris, Caledonia, Dunnville and New Hamburg can be reduced 91 percent by channelization and dyking as compared to a 54-56 percent reduction by the Montrose reservoir, the most efficient of the eight reservoirs investigated. Channelization and dyking is the most cost-effective structural method of reducing flood damages. In order to be effective, each dyking and channelization project should be completed as soon as possible.

2. It is recommended that Grand River Conservation Authority policies for regulating floodplain development be continued in accordance with provincial policies and guidelines and that basin municipalities incorporate floodplain restrictions in their official plans and zoning by-laws.

Regulating floodplain development is the best means of reducing or eliminating future flood damages. While structural projects such as dyking and channelization are useful in reducing flood damages, they do not guarantee immunity from floods at all places and at all times.

3. While existing Grand River Conservation Authority policies control the placing and dumping of fill in defined areas, it is recommended that these policies be strengthened by the inclusion of a registered fill line along the river valleys.

Section 28 (f) of the Conservation Authorities Act enables conservation authorities to prohibit or control the placing or dumping of fill in defined areas. In order to enforce this section of the Act, the Authority must designate the area affected by such dumping with fill lines. At present, only specific source areas are protected by fill lines. Designated areas should be expanded to include basin watercourses.

4. It is recommended that the Eramosa valley wetlands be preserved and protected from development by planning controls and by acquisition.

These wetlands adjacent to the river reduce flows by retarding runoff and reducing peak flows. They also maintain a high water quality by acting as buffer strips between the adjoining agricultural lands and the river. A high water quality ensures a low cost supplementary water supply for Guelph and a suitable habitat for a cold-water fishery in the Eramosa river.

5. It is recommended that a study be carried out to determine what land use practices are causing an increase in flood flows and flood volumes on the Grand river and what the effects of future land use practices upon flood flows might be.

At Cambridge (Galt), flood volumes have increased 18 percent and the frequency of flood occurrences has more than doubled in the last forty years, but the study was unable to come to a firm conclusion as to the causes.

C. Recommendations for Providing Adequate Water Supply

The basin study determined that the future water needs of the major urban areas can be obtained by:

- a) developing new ground water sources for Cambridge and Guelph
- b) developing a new surface water source from the Grand river for Waterloo and Kitchener
- c) continued withdrawal from the Grand river for Brantford.

All other basin communities except Elora and Fergus can meet future demands from existing supplies. Elora and Fergus can meet future demands by developing new ground water sources.

1. It is recommended that the municipal ground water supplies for Kitchener-Waterloo be supplemented by further water withdrawals from the Grand river.

These withdrawals can be accomplished by induced infiltration wells near the river and by pumping from the river to recharge ground water at the Mannheim well field. Testing is presently being carried out by the Regional Municipality of Waterloo to determine the feasibility of this scheme.

2. It is recommended that prior to the final development of the above water supply system:

- **a) industrial organics presently seeping from abandoned industrial waste disposal sites at Breslube Enterprises, near Kitchener, be eliminated or prevented from reaching the adjacent Grand river**
- **b) a water quality surveillance program be established to evaluate risks from possible contamination of the water supply from any sources of synthetic organic compounds.**

The most notable potential sources of organic chemicals are the Uniroyal Ltd. plant at Elmira on Canagagigue creek and the Waterloo sewage treatment plant on the Grand river. The recommended surveillance program should be developed to protect existing and future surface water supplies, particularly for the Cities of Kitchener, Waterloo and Brantford.

3. It is recommended that:

- **a) new ground water supplies be developed near Cambridge to meet future demands**
- **b) the City of Guelph investigate the feasibility of developing new ground water supplies, directing its attention toward the southeast of Guelph in order to meet future demands past the year 2001**
- **c) Elora and Fergus carry out test drilling in a nearby buried bedrock valley to assess its potential for future municipal supplies.**

A recent study by the Regional Municipality of Waterloo indicated that there are additional ground water supplies located in the areas east and south of Cambridge.

For Elora, Fergus and Guelph, it is estimated that existing supplies can meet average daily demands for a 2001 medium population projection. The Grand river basin study has identified favourable locations for test drilling in these areas.

4. It is recommended that a ground water quality network be established to monitor the major water supply aquifers within the basin.

A ground water surveillance network should be established in the basin to deal with existing site-specific problems of contamination or possible contamination of usable ground water supplies. In particular, the network should monitor heavy metal, pesticides and other inorganic and organic compounds. This network should be established as soon as possible. This undertaking should be carried out in conjunction with the surface water surveillance program recommended in C.2 (b).

5. It is recommended that the water conservation program be continued in the Regional Municipality of Waterloo, particularly in Waterloo, Kitchener and Cambridge, in order to reduce municipal water demands. For other municipalities, the pursuit of water conservation programs should be evaluated in relation to future needs and supply capabilities.

Water conservation programs embrace a range of actions that aim at reducing average and maximum day municipal water demands. A moderate conservation program could be expected to reduce average day demand in Kitchener-Waterloo by 10 percent, and in Cambridge by 15 percent.

Conservation practices that have been adopted in Guelph are supported and encouraged in light of the potential water supply problem that may occur after the year 2001.

Included in any conservation program should be the consideration of revising the existing rate structure. Where appropriate, municipalities should consider moving from a decreasing rate structure to a rate structure that encourages water conservation.

System losses or unbilled consumption appear to be approximately 9 percent higher than the provincial average for Guelph and Brantford. Existing programs to trace and reduce these losses should be continued.

D. Recommendations to Maintain Adequate Water Quality

The basin study concluded that water quality in the central Grand river can be improved by increased levels of sewage treatment at the Kitchener and Waterloo sewage treatment plants. Some improvement in water quality can also be obtained by reducing upstream rural non-point sources, particularly through the use of erosion control measures.

Water quality in the Speed river will be improved by the recently completed advanced sewage treatment facilities at Guelph. If required, further improvement can be attained by the installation of additional phosphorus removal facilities.

1. In order to increase dissolved oxygen levels and eliminate ammonia toxicity in the central portion of the Grand river, it is recommended that advanced sewage treatment facilities be installed at the Kitchener sewage treatment plant as soon as possible, and at the Waterloo sewage treatment plant at a later date depending on population growth (advanced treatment at the Waterloo plant would be needed by the year 2001 for a medium population projection).

An increased level of sewage treatment at Kitchener and Waterloo will improve the water quality to a reasonable level in the central Grand river, but the provincial water quality objective for dissolved oxygen of 4 mg/L will not always be met in certain sections. Plan B2, through the use of flow augmentation from the Montrose reservoir, comes closest to achieving the objective.

Converting ammonia nitrogen to the nitrate form using rotating biological contactors (RBCs) and accompanying dual-media filters at Kitchener and Waterloo is one method of improving the quality of sewage effluent, thus increasing dissolved oxygen levels and reducing ammonia toxicity in the rivers. The cost of this treatment is included in all plan cost estimates.

Achieving the dissolved oxygen objective continuously in all sections of the central Grand river would require drastic deductions of oxygen-demanding wastes and phosphorus from all point and upstream rural non-point sources. Such large reductions from all point sources would be exceedingly expensive. Large reductions from non-point sources may be difficult to achieve. Reductions will require long-term, continuing improvements in technology and land use practices.

2. It is recommended that the impact of the Guelph advanced sewage treatment facilities on the water quality of the lower Speed river be evaluated throughout the next few years to determine if additional treatment is required.

The total effluent characteristics of the recently completed sewage treatment addition (rotating biological contactors and dual-media filtration) are not yet known. Assumed effluent characteristics were used for analyzing the basin study water management alternatives. If after a 2-3 year evaluation period, the Speed river between Guelph and Cambridge (Hespeler) is still experiencing very low oxygen levels, consideration must be given to reducing further the levels of phosphorus in the sewage effluent. One method of reducing phosphorus considered by the basin study is the addition of chemical treatment and multi-media filtration at the Guelph sewage treatment plant. The cost of this treatment is included in all the plan cost estimates.

3. In order to evaluate the effects of existing and proposed water quality improvements it is recommended that the Ministry of the Environment and the Grand River Conservation Authority jointly maintain the existing six continuous water quality monitoring stations in the central Grand river and the lower Speed river.

With the addition of remote sensing, these gauges would also aid in the real-time operation of existing reservoirs and sewage treatment plants.

4. It is recommended that the Ministry of Agriculture and Food, as the lead agency, carry out studies to determine the effectiveness, type and site specific locations of rural non-point source controls. Initially, efforts should be concentrated in the Canagagigue creek, middle Grand river, Irvine creek, Cox creek, Conestogo and Nith river sub-basins.

Studies should be carried out to determine:

a) those critical areas contributing the greatest loadings of sediments and nutrients to the streams. Improved management practices should be concentrated in these areas
b) the applicability and effectiveness of various rural non-point source management practices
c) the relation between the costs of these measures and the agricultural and water quality benefits obtained
d) priority of the areas to be treated.

5. It is recommended that urban areas adopt storm water management practices to reduce local flooding and improve stream water quality.

This study has shown that urban runoff does not affect the flood peak flows of the major rivers nor does it materially affect the dissolved oxygen regime in the Grand or Speed rivers. However, urban runoff increases bacteria levels immediately downstream of the major urban centres on these rivers. Increased levels of bacteria pose potential health hazards for incidental contact such as children playing at the river's edge. Urban runoff causes more serious flooding and water quality problems in small tributaries by raising stream levels rapidly and increasing concentrations of metals, bacteria and nutrients.

6. In order to achieve the flow requirements of plan A4 for both water supply and water quality, it is recommended that the Grand River Conservation Authority operating policy for the existing reservoirs be modified to achieve the following target flows:

Location	Period	Minimum Flow Targets		Operating Range*	
		Present	Recommended	Present	Recommended
Grand R. at Shand Dam	June-Sept.	2.8 m^3/s	2.8 m^3/s	N/A	N/A
	May-Oct.	2.8 m^3/s	2.8 m^3/s	N/A	N/A
	Nov.-Apr.	None	2.8 m^3/s	N/A	N/A
Grand R. at Doon	May-Oct.	11.3 m^3/s	9.9 m^3/s	11.3 - 12.7 m^3/s	9.1 - 10.8 m^3/s
	Nov.-Dec.	No Target	7.1 m^3/s	N/A	6.2 - 7.9 m^3/s
	Jan.-Apr.	Ice ** Conditions			
Grand R. at Brantford	May-Oct.	17.0 m^3/s	17.0 m^3/s	17.0 - 18.4 m^3/s	15.6 - 18.4 m^3/s
	Nov.-Dec.	No Target	No Target	N/A	N/A
	Jan.-Apr.	Ice ** Conditions			
Conestogo R. at Conestogo Dam	May-Oct.	2.1 m^3/s	2.1 m^3/s	N/A	N/A
	Jan.-Apr.	No Target	No Target	N/A	N/A
Speed R. at Guelph Dam	May-Oct.	0.6 m^3/s	0.6 m^3/s	N/A	N/A
	Jan.-Apr.	No Target	No Target	N/A	N/A
Speed R. at City of Guelph (Hanlon Expressway)	June-Sept.	1.1 m^3/s	1.7 m^3/s	N/A	N/A
	May-Oct.	1.1 m^3/s	1.1 m^3/s	N/A	N/A
	Jan.-Apr.	Ice ** Conditions			

* Because of the travel time from the reservoirs to the point of interest, the daily flows can vary from the target flow. The travel times from the reservoirs to Doon and Brantford are 30 and 48 hours respectively.

** When the river is ice covered, flows cannot be continuously measured.

N/A Not Applicable

E. Recommendation to Protect the Montrose Reservoir Site

1. It is recommended that the Montrose reservoir site be protected for possible future water management purposes.

Protection of the Montrose reservoir site can be achieved by land acquisition and planning controls. Acquisition can be carried out over time by purchasing the land at the prevailing market price. Planning controls can be utilized in the form of land use regulations and zoning.

At some time in the future the land can either be sold, used for construction of a dam and reservoir, or preserved for other uses. In the meantime, the existing agricultural land use can be maintained and the site protected from development.

F. Recommendations to Implement the Plan and Co-ordinate Government Activities

1. It is recommended that the water management plan be implemented by existing government agencies.

Traditionally, the components of plan A4 have been implemented by the following agencies:

Flood control, flood warning, dyking and channelization	— Grand River Conservation Authority Municipalities Ministry of Natural Resources
Flood proofing	— Individual landowners
Water supply projects and sewage treatment plants	— Municipalities Ministry of the Environment
Acquisition of Montrose reservoir land	— Grand River Conservation Authority
Non-point source pollution control	— Individual landowners Municipalities Grand River Conservation Authority Ontario Ministry of Agriculture and Food Ministry of the Environment Ministry of Natural Resources
Planning controls	— Municipalities Grand River Conservation Authority Ministry of Municipal Affairs and Housing Ministry of Natural Resources

2. It is recommended that a committee be established to co-ordinate the activities of the existing agencies in implementing the water management plan preferred by governments.

The committee would consist of members from implementing ministries and agencies and basin municipalities. The committee would deal with the scheduling and implementation of measures selected to meet the water management needs of the basin.

3. It is recommended that such a co-ordinating committee play a lead role in carrying out a periodic re-evaluation of the plan, co-ordinating investigations and recommending new or modified alternatives to achieve the water management objectives of the Grand river basin.

The selected basin plan should be reviewed on an on-going basis and re-evaluated every five years. This will ensure that the plan is kept abreast of the latest developments in water resources management and that the assumptions made in deriving the original plan are still valid.

4. It is recommended that the co-ordinating committee be assisted in its on-going review by a small technical staff responsible to the co-ordinating committee.

The technical staff would aid the co-ordinating committee in reviewing the management plans and undertaking specific water management studies. The capability of this staff can be expanded as the need requires, by drawing upon the expertise of the basin universities and other agencies.

COMPARISON OF MAIN PLANS — MEDIUM POPULATION PROJECTION

Plan	Costs	Benefits	Advantages	Disadvantages
	Present value at 6%, millions of 1979 dollars			
Plan A1, A2 • Dyking and channelization at New Hamburg, Cambridge (Galt and Preston), Paris, Brantford, Caledonia and Dunnville • Advanced sewage treatment for Kitchener, Waterloo and Guelph • Local sources of water supply Plan A1 - new ground water supplies for Cambridge Plan A2 - new water supply to Cambridge via Mannheim recharge system	68* 66*	121 121	1. Lowest cost solution. 2. Minimal environmental and social impacts, localized to dyking and channelization sites. 3. Water quality on Grand and Speed rivers generally is improved, but does not meet MOE D.O. objective fully near Kitchener and Guelph. 4. Provides urban flood protection against floods greater than 100-year flood at sites with dyke protection (91% reduction in flood damages). 5. Meets water supply needs. 6. Socially most acceptable as reflected by Public Consultation Working Groups.	1. Lower water quality on Grand river (Waterloo to Paris) than B1, B2. 2. No additional flood protection for areas not provided with dykes. 3. Flood damage reduction provided only if dyke projects are carefully planned and co-ordinated.
Plan A3 • Same as A1 plus Everton reservoir on Speed river	84*	121	1. Flood protection and water supply same as A1. 2. Water quality on Speed river below Guelph is better than A1, but still does not meet MOE D.O. objective fully.	1-3. Same as A1. 4. Has detrimental impact on cold water fishery in reservoir site. 5. Reservoir increases A1 costs by $16 M.
Plan A4 • Same as A1 plus appropriate measures to be taken to preserve the Montrose reservoir site for possible future use	72* (Montrose lands disposed of in 2001) 83* (Reservoir constructed in 2001)	121 121	1. Water quality, flood protection and water supply same as A1. 2. Minimal environmental impacts (unless dam is constructed in the future). 3. Gradual social impacts during land acquisition. 4. Flexibility to handle future water quality uncertainties is increased. 5. Permits continued agricultural use of lands in reservoir acquisition area.	1-3. Same as A1. 4. Does not eliminate uncertainty about future land use. 5. No assurance that land-use planning can preserve the reservoir site except through provincially imposed regulations or purchase. 6. $4 M more costly than A1 if the reservoir is not built and $15 M more costly if the reservoir is built.
Plan B1 • Montrose dam • Advanced sewage treatment at Kitchener and Guelph • Local sources of water supply same as A1	74*	116	1. Water quality on Grand and Speed rivers is improved over Plan A, but still does not meet MOE D.O. objectives fully near Kitchener and Guelph. 2. Provides flood protection against a 10-year flood. 3. Provides additional flood protection for rural areas. 4. Meets water supply needs with greater flexibility for possible future needs. 5. Reservoir provides additional recreational opportunities.	1. Costs $6 M more than A1. 2. Has detrimental social and environmental impacts. 3. Provides less flood protection than A1. 4. Has considerable local opposition.
Plan B2 • Montrose dam • Dyking and channelization same as A1 • Advanced sewage treatment at Kitchener and Guelph • Local sources of water supply same as A1	97*	122	1. Same as B1. 2. Provides urban flood protection against floods greater than a 100-year flood (96% reduction in flood damages) as A1. 3. Reduces the risk of dyke failure by reducing flood peaks. 4. Provides added protection if future flood flows increase due to changing land-use practices. 5. Provides additional flood protection for rural areas. 6. Meets water supply needs with greater flexibility for possible future needs. 7. Reservoir provides additional recreational activities.	1. Costs $29 M more than A1. 2. Has detrimental social and environmental impacts. 3. Has considerable local opposition.
Plan C1 • St. Jacobs dry reservoir with dyking and channelization at New Hamburg • Advanced sewage treatment same as A1	70*	115	1. Less environmental impact than Montrose dam. 2. Provides urban flood protection against a 10-year flood and reduces flood damage by 50-49%. 3. Water quality on the Grand and Speed rivers improved, but does not meet MOE D.O. objective fully near Kitchener and Guelph. 4. Meets water supply needs. 5. $27 M less costly than B2.	1. Has detrimental social impact. 2. Provides less urban flood protection than A1, A2, B1 and B2. 3. $2 M more costly than A1.
Plan C2 • Montrose small dry reservoir, 24.7 million cubic metres (20,000 acre-ft) with dyking and channelization at New Hamburg • Advanced sewage treatment same as A1 • Local sources of water supply same as A1	73*	116	1-4. Same as C1. 5. $24 M less costly than B2. 6. Reduces flood damages by 56-54%.	1-3. Same as C1. 4. $5 M more costly than A1.
Plan C3 • Montrose large dry reservoir, 77.7 million cubic metres (63,000 acre-ft) with dyking and channelization at New Hamburg • Advanced sewage treatment same as A1 • Local sources of water supply same as A1	87*	116	1-4. Same as C1. 5. $10 M less costly than B2. 6. Reduces flood damages by 57-56%.	1-3. Same as C1. 4. $19 M more costly than A1.
Plan D • Pipeline from Lake Erie • Dyking and channelization same as A1 • Advanced sewage treatment same as A1	331**	80	1. A secure source of water supply (water supply needs are met). 2. Provides urban flood protection against floods greater than a 100-year flood at sites with dyke protection (91% reduction in flood damages). 3. Water quality on the Grand and Speed rivers improved, but does not meet MOE D.O. objective fully near Kitchener and Guelph. 4. Services cities along the Grand river from one source with capacity limited only by design and cost considerations.	1. Highest cost plan. 2. Large short-term environmental impact along route. 3. High energy use for pumping - over $5 M annual operation costs. 4. Flood damage reduction provided only if dyke projects are carefully planned and co-ordinated.

* Costs listed do not include discounted cost of $94 M for conventional sewage treatment plant expansions.
** Costs listed do not include discounted cost of $89 M for conventional sewage treatment plant expansions.

POOR

QUALITY

ORIGINAL